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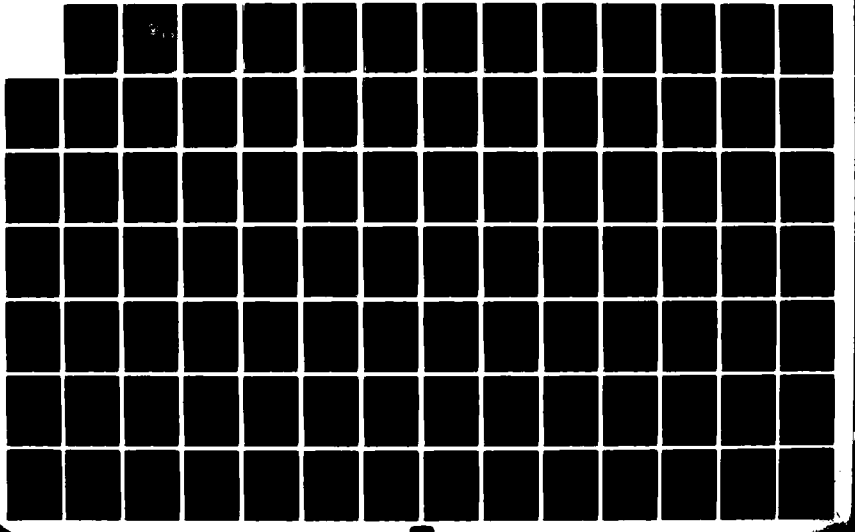

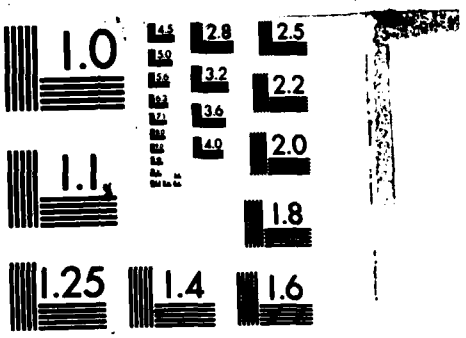

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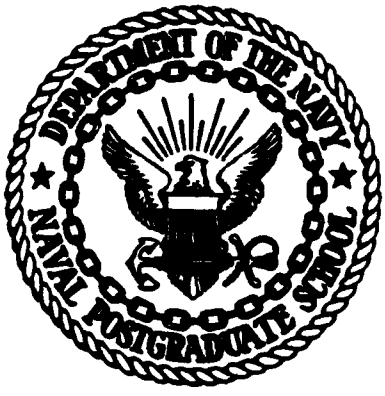

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MARINE STEAM CONDENSER
DESIGN OPTIMIZATION

by

Thomas M. Buckingham

December 1983

Thesis Advisor: R. H. Nunn

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A138 568	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Marine Steam Condenser Design Optimization		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; December 1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Thomas M. Buckingham		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		12. REPORT DATE December 1983
		13. NUMBER OF PAGES 224
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Condenser Optimization
CONDIP
ORCON1
Condenser Computer Program

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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Marine Steam Condenser Design Optimization

by

Thomas M. Buckingham
Lieutenant, United States Navy
B.A., College of the Holy Cross, 1977

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
December 1983

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ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation tc Professor Robert Nunn and Professor Gary Vanderplaats for their advice and guidance during the development of this project. Without their encouragement and valuable assistance this thesis could never have been completed.

Many thanks and appreciation are due my wife, Susan, for her understanding, encouragement and participation in this endeavor.

Finally, this thesis is dedicated tc Louis Perra, a close friend, whose pride and faith in my goals and ability inspired me to do the best job possible.

I. INTRODUCTION

A. BACKROUND

For many years the steam plant was unchallenged in its role as the primary type of marine propulsion systems. But recently gas turbines have become a desirable alternative despite the fact that they are less efficient than comparable steam plants. The primary advantage of gas turbines is their light weight and compact size. Thus, in order for the marine steam plant to survive, it is imperative that lighter, more compact and efficient steam plants be developed.

While there are numerous advanced concepts in all areas of steam propulsion which can be explored, one simple way to streamline the steam plant is the elimination of overdesign. Most overdesign is due to unnecessary safety factors used to offset lack of detailed knowledge about the thermal processes in the plant. Identification of the minimum safe design could significantly reduce unnecessary overdesign and result in the development of a smaller, more compact power plant.

B. METHODOLOGY

In the United States the most prevalent criterion for the design and specification of surface condensers is based on the "square-root of V" relationship, as developed by the Heat Exhange Institute (HEI) [Ref. 1]. The HEI method was adopted by the Department of the Navy Bureau of Ships (now Naval Sea System Command) for specification of U.S. Naval condensers.

The HEI method is very simple in its approach, calculating the overall heat transfer coefficient as a function of cooling water velocity through the tubes, inlet coolant temprature, tube wall thickness and material, and fouling. The limitations of this method are apparent. Designs based on HEI are insensitive to shell-side conditions. Saturation steam pressure, temperature and enthalpy are assumed to be constant as steam passes through the bundle, whereas in reality there is a continual pressure drop as steam flow passes over the rows of tubes, with a corresponding decrease in saturation temperature. There is also no provision for any effects of condensate film, external tube enhancement, etc. on the shell-side of the bundle. In addition, the HEI method does not account for the presence and effect of non-condensible gases that inevitably contaminate a condenser.

With the capabilities of high speed computers now available, more comprehensive methods have been developed to account for the deficiencies of the HEI method. In particular, a radial flow computer code was developed to calculate the local heat transfer and thermodynamic properties on a row by row basis. Known as ORCON1, this code was developed by Oak Ridge National Laboratory (ORNL) under contract to the Office of Saline Water during the period from 1968-1970 [Ref. 2]. The program was based, in part, on the work performed by Eissenberg [Ref. 3]. Eissenberg's experimental results led to correction factors on the basic Nusselt equation to acccunt for condensate inundation effects on tubes within a condenser bundle. Basically, ORCON1 divides the condenser into sectors and performs a row by row analysis within each sector, determing local heat transfer coefficients, heat flux, steam characteristics, the affect of condensate inundation and numerous other parameters at each row. ORCON1 is also capable of incorporating the effects of both tube-side and steam-side enhancement factors. Since

ORCON1 represented a much more comprehensive and detailed analysis of the condenser then the less exact HEI method, its results could be expected to be more precise.

Some work has been done at the Naval Postgraduate School to improve the capabilities of ORCON1. In his development of OPCODE2, Johnson [Ref. 5] added subroutines to ORCON1 which calculated tube-side pressure drops, corresponding pumping power and condenser volume. Nunn and Marto [Ref. 14] have incorporated the effects of vapor shear in an amended version of ORCON1 called MORCON. MORCON includes the correlations developed by Fujii [Ref. 4] to determine the effect of vapor velocity on the thermal resistance of the condensate film on the condenser tubes. In general, vapor shear effects tend to enhance the condenser heat transfer on the steam-side of the tube while condensate inundation tends to inhibit it.

The ability to represent numerically the actual thermodynamic processes occurring within the condenser has improved dramatically. However, the capability to couple these increasingly comprehensive and complex condenser design programs with an optimizing procedure has not made comparable progress. Optimization is a powerful tool which can help in reducing overdesign and achieving the goal of a safe compact condenser design.

There are currently numerous computer optimization programs available which can be coupled with general design programs of all types to numerically improve and ultimately determine the best design. The key is to properly write the design program so that it is compatible with the optimizer. Johnson [Ref. 5] developed a computer program called OPCODE1, based on the HEI method of condenser design, and was able to couple it with one such numerical optimizer. The results of OPCODE1 demonstrated how condenser designs can indeed be safely improved upon. It also revealed the

versatility of condenser design optimization as a powerful design tool. However, Johnson was unsuccessful in coupling OPCODE2 (his derivative of ORCON1) with an optimizer. This failure does not alter the fact that that in order to fully appreciate more sophisticated condenser design analyses, such as that used in ORCON1, it is imperative that computer programs be developed which will be compatible with current numerical optimizers.

C. OBJECTIVE

There were two primary objectives of this thesis. The first objective was to develop a computer code which incorporates the basic condenser analysis of ORCON1 and the subsequent improvements made in MORCON and OPCODE2, but which will be capable of being coupled with a numerical optimizer to yield a complete, detailed design package. This design package can then be used as a tool in obtaining a much more reasonable conceptual design and for use in comparison studies. It would provide the naval architect the ability to optimize weight, volume, cost or any other potential design objective of the marine plant.

The second objective was to make this design package capable of determining the single best design rather than simply an improvement over the initial design. The key was to construct the program in such a way so the optimizer does not stop at some relative optimum, but continues the analysis until no further improvement can be realized. It is most desirable to be able to reach this single true optimum design regardless of initial design variable values.

II. NUMERICAL OPTIMIZATION

A. BACKGROUND

Nearly all design problems require either the minimization or maximization of a parameter. This parameter will be called the problem's objective function or design objective [Ref. 6]. For a given design to be feasible or acceptable, it must satisfy a set of design constraints which are either maximum or minimum limiting values for a pre-determined set of parameters or functions of parameters. For example, in any condenser design the outer diameter of a condenser tube can never be less than zero and there is normally some practical upper limit which also cannot be exceeded. These limits are design constraints on the tube outer diameter. In the design problem there is also a set of design variables which are parameters whose values can be changed within specified limits in order to minimize or maximize the design objective. For example, in minimizing the condenser volume an engineer may want to vary tube inner diameter, tube wall thickness and tube length. These three parameters would thus be examples of typical design variables.

For such complex design problems as the treatment of the condenser design in ORCON1, it is necessary to choose an optimization scheme which can handle the problem and provide a rational, rapid approach to design automation and optimization. An optimization program based on direct methods for solution of constrained problems [Ref. 11] was chosen for this research work.

B. CONSTRAINED FUNCTION MINIMIZATION (CONMIN)

Vanderplaats [Ref. 7] developed an optimization program, CONMIN, capable of optimizing a very wide class of engineering problems. CONMIN is a fortran program, in subprogram form, that optimizes a multi-variable function subject to a set of inequality constraints.

It is practical at this point to introduce three basic definitions and their respective conditions [Ref. 8].

DESIGN VARIABLES: Those parameters which the optimzation program is permitted to change in order to improve the design. Design variables appear only on the right side of an equation, are continuous, and have continuous first derivatives.

DESIGN CONSTRAINTS: Any parameter which must not exceed specified bounds for the design to be acceptable. Design constraints may be linear or nonlinear, implicit or explicit, but they must be functions of the design variables. Design constraints appear only on the left side of equations.

OBJECTIVE FUNCTION: The parameter which is going to be minimized or maximized during the optimization process. The objective function may also be either linear or nonlinear, implicit or explicit, and must be a function of the design variables. The objective function usually appears on the left side of an equation. The only exception is if the objective function is also a design variable.

Assuming that the optimization process requires the minimization of a particular objective function the general optimzation problem can be stated as:

Find the vector of design variables, $\underline{X}$,
To minimize the objective function, $F(\underline{X})$,
Subject to the constraints:

$$G_j(\underline{X}) \leq 0.0 \qquad j = 1,NCON \qquad \text{(eqn 2.1)}$$

$$VLB_i \leq \underline{X} \leq VUB_i \qquad i = 1,NDV \qquad \text{(eqn 2.2)}$$

In the general problem, $G_j(\underline{X})$ are the constraint functions; there are NCON constraints and NDV design

variables; VLB_i and VUB_i are the lower bounds and upper bounds of the i-th design variable. If the equality condition is met, ($G_j(\underline{X})=0.$), the constraint is active. If the inequality is met, ($G_j(\underline{X})<0.$), the constraint is inactive. Finally, if the inequality of equation 2.1 is violated, ($G_j(\underline{X})>0.$), that constraint is said to be violated. Because of numerical inaccuracies representing exact zero on the computer, the equality condition is represented by a band around the value $G_j(\underline{X})=(0.\pm CT)$ where CT is the constraint thickness.

Any design which satisfies the inequalities of equations 2.1 and 2.2, thus having no violated constraints, is said to be feasible. If the design violates any of these constraints it is said to be an infeasible design. The design which best minimizes the objective function while still remaining feasible is said to be optimal.

, CONMIN requires an initial set of values for the design variables $\underline{X}$ to obtain an initial design which is either feasible or infeasible. If the initial design is feasible, CONMIN moves in a direction which will minimize the objective function. If the initial design is infeasible, CONMIN moves toward a feasible solution with minimal increase in the object function.

The optimization process proceeds in an iterative fashion. Johnson [Ref. 5] presents in greater detail the procedures utilized in CONMIN to search for the minimum objective value. In general, the methods used by CONMIN to determine search direction include the method of steepest descent, the method of conjugate direction, and the method of feasible directions. For further background concerning CONMIN and the numerical techniques utilized in optimization, consult Vanderplaats [Ref. 7], Fletcher and Reeves [Ref. 9], Zoutendijk [Ref. 10], and Vanderplaats and Moses [Ref. 12]. However, it is necessary to stress a few pertinent points which will aid in understanding how the program was developed in this thesis.

The optimization process begins by calculating the gradient of the objective function using a finite difference technique. A perturbation is applied to each of the design variables in a single forward step and the gradient vector is determined.

$$\Delta F(\underline{X}) = \begin{bmatrix} \frac{\partial F(\underline{X})}{\partial X} \\ \\ \frac{\partial F(\underline{X})}{\partial X} \end{bmatrix}$$

The search direction is then calculated and is a function of this gradient and any active or violated constraints resulting from the applied perturbation. Subsequent search directions are a function of previous search directions, as well as current gradient information and any appropriate constraint factors. Obviously, the size of the perturbation and the size of the bandwidth about an active constraint will have a great deal of effect on the search direction and ultimate optimization process. This detail will be recalled later-on during the code development.

There are some limitations to CONMIN. The number of design variables (NDV) directly affects the computational time required to reach an optimum. Since the calculation of the gradient information required for each design variable at the beginning of each design iteration is found by using a single forward finite difference step, requiring a complete pass through the analysis portion of the program, there is an increase in CPU time as NDV inceases. Also, as NDV increases, there is the corresponding rise in machine related numerical innacuracy. Vanderplaats [Ref. 6] recommends no more than twenty as a practical limit for the number of design variables.

It is quite possible that while design improvement may be obtained, the single best design optimum or true optimum

may not be reached. This is not an uncommon occurrence and there are several possible explanations. For example, the design problem may not be formulated properly or the analysis may be extremely complex and non-linear. However, a more common reason is that there are "relative optimums" between the initial design and the single true optimum. This concept of relative vs true optimum design can be better explained through an analogy. The search for the best optimum design can be likened to a blind man climbing to the top of a mountain. The blind man knows he is proceeding up the mountain by sensing the direction of ascent. However, the paths he takes may be limited by barriers or fences which will restrict the directions he can go. These fences represent constraints in the optimization problem. During the journey he may also encounter small crests and valleys. If the available paths lead the blind man up to one of these crests prior to reaching the mountain top, he will be confronted with a situation where he will sense no further rate of ascent and he will stop his journey. So although he has made progress from his initial starting point, the man did not achieve his ultimate goal of climbing the mountain.

During optimization, the search for a true optimum may proceed along a path on which the objective function assumes such relative optimum values. If the optimizer can not be made to "look beyond" these relative peaks, then the optimization will cease - at a design which may be an improvement over the initial one but short of the true optimum. This problem may be overcome by starting the design with several different initial design vectors, $\underline{X}$, until the same optimal design is repeated. Another alternative may be to increase the size of the finite difference so that the optimizer uses larger perturbations of $\underline{X}$ thus looking beyond any small increases in the objective function which could stand in the way of further design progress. This second

alternative will be specifically addressed during the discussion of the code development.

C. CONTROL PROGRAM FOR ENGINEERING SYNTHESIS (COPES)

The optimizer, CONMIN, was written in subroutine form. Vanderplaats [Ref. 13] has developed a main program to simplify the use of CONMIN and aid in the design optimization process.

The user must supply an analysis subroutine called ANALIZ, which consists of three segments: input, analysis and output. COPES acts as an interface between ANALIZ and the optimizer CONMIN. Based on a flag from COPES (ICALC=1,2,3) ANALIZ performs the proper function. Figure 2.1 offers a simplified illustration of the interrelationship between COPES, ANALIZ and CONMIN.

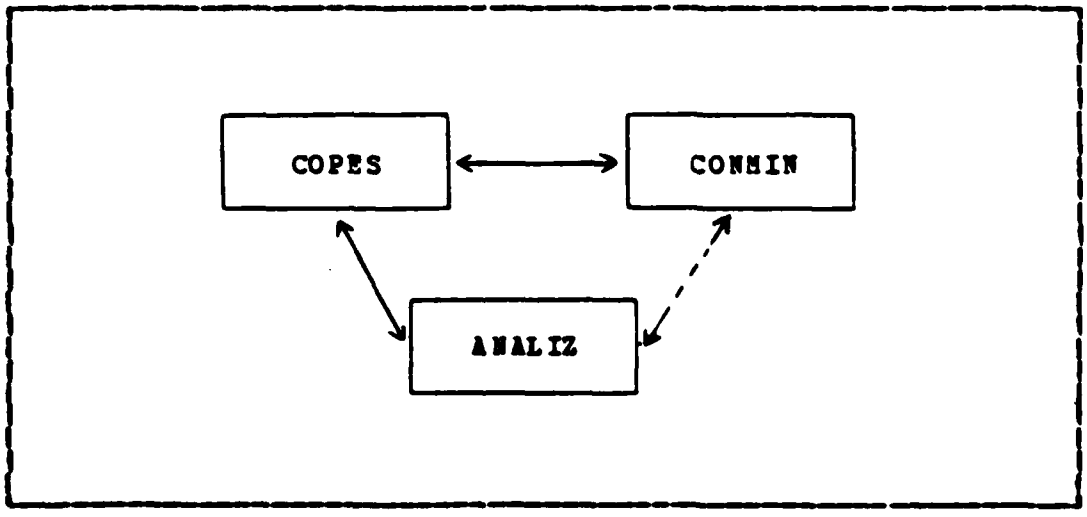


Figure 2.1 Flow Diagram For ANALIZ and COPES/CONMIN.

COPES currently provides four specific capabilities, two of which will be applied in this work:

1. Single analysis - just as if COPES/CONMIN were not used.
2. Optimization - minimization or maximization of a multivariable function with corresponding constraints.

COPES requires certain initial data from the user in order to coordinate the optimization process. Initial values for the design variables as well optimizer control parameters are utilized by CONMIN to conduct its numerical analysis. There are a few optimizer parameters which are particularly important to the treatment of condenser designs. One is the finite difference step used in gradient calculations. Another is the normalization factor used in COPES evaluation of a constraint function. COPES utilizes the following expressions in determining constraint function violations:

$$\frac{BU - CFV}{SCAL1} \leq 0.$$

$$\frac{CFV - BL}{SCAL2} \leq 0.$$

where SCAL1 and SCAL2 are the normalization factors, BU and BL are the upper and lower limits of the constraint, and CFV is the constraint function value. It is intuitive that the normalization factor can play an important role in determining the size of the active region about a given design constraint. Both finite difference and constraint normalization will be recalled later during the code development.

The power of COPES is that it has simplified the procedures involved in using a sophisticated program such as CONMIN. The user is therefore freed from the unwanted role of systems analyst and can concentrate on the design analysis.

III. CONDENSER DESIGN IMPROVEMENT PROGRAM (CONDIP)

A. BACKGROUND

In the late 1960's, engineers at the Oak Ridge National Laboratory developed a sophisticated computer code under contract to the Office of Saline Water. This code, called ORCON1, [Ref. 2] was generated to aid in the analysis and parametric study of large, generally circular condensers. Much of ORCON1 was dependent on Eissenberg's research work [Ref. 3] on the effects of condensate rain on the shell-side convective heat transfer coefficient. Johnson [Ref. 5] took ORCON1 and made a few minor modifications to determine tube side pressure losses and volumetric calculations. Nunn and Marto [Ref. 14] further incorporated the correlations proposed by Fujii [Ref. 4] to determine the effects of shearing forces exerted by high vapor velocities on the condensate film and resulting shell-side heat transfer coefficient.

It was at this point that the development of CONDIP was begun. CONDIP was dependent primarily on the principles detailed in ORCON1 but also incorporated subsequent developments to the basic program. CONDIP was written , however, in such a way as to be compatible with the optimizer, CONMIN.

CONDIP analyzes a single or double pass, circular or semicircular condenser, with steam flowing radially inward on the shell-side of the tubes and variable salinity water flowing on the tube-side. An optional, rectangular air cooler bundle is provided-for as well as shell-side baffles. The circular bundle is normally divided into 30-degree sectors with symmetry about the central axis to reduce computational effort. Unless otherwise specified, tubes are

placed on a 60-degree equilateral, triangular pattern of concentric rows with the rows added from an inner void out to the outermost row. The void serves as a collection header for non-condensible gases prior to passage through an air cooler, if specified. As in ORCON1, CONDIP proceeds sector by sector, row by row through the condenser utilizing an average tube to represent the row segment, and calculates the following quantities in each sector:

a) Steam pressure losses at the entrance of a sector.
b) Total pressure of the steam/non-condensible gas mixture entering a row segment.
c) Saturation pressure of steam entering a row segment.
d) Saturation temperature of the steam entering a row segment.
e) Steam flow entering the row segment.
f) Velocity of the steam/non-condensible gas mixture at the minimum cross-section in the row segment.
g) The fraction of non-condensible gas in the mixture by weight.
h) The overall heat transfer coefficient for the average tube in the row segment.
i) The steam-side condensing coefficient.
j) The tube-side heat transfer coefficient.
k) The shell-side film heat transfer coefficient composed of the non-condenible gas film and the condensate film.
l) The shell-side friction factor.
m) The shell-side pressure loss as steam passes over the row segment.
n) The shell-side Reynolds number based on the mass flow at the minimum cross-sectional area in the row segment.
o) The heat transfer rate per square foot of condenser tube.
p) The mass flow rate of steam/non-condensable gas mixture at the minimum cross-section in the row segment.

q) The mass flow of condensate produced as steam passes over the row segment.

r) The cooling water temperature at the outlet end of the condenser.

s) The coolant pressure loss on the tube-side.

t) The average Reynolds number of the coolant through the tube.

u) The heat transfer coefficient for the non-condensible gas film.

v) The internal heat film heat transfer coefficient.

w) The number of tubes per row segment.

x) The cross-section area available for steam flow per row segment.

y) The cumulative shell-side pressure drop.

z) The LMTD based on inlet and outlet coolant temperatures and saturation temperature at each row segment.

In addition to the above parameters, the area-weighted overall heat transfer coefficients for the condenser, cooler and combined condenser are used to calculate the "back calculated" log mean temperature difference (LMTD). Steam exit-fraction, condenser volume, coolant pumping power and numerous other factors are calculated from the cumulative results of the row and sector analysis.

There are two significant contributions to the external film heat transfer coefficient which have a profound impact on the overall analysis. As mentioned earlier, Eissenberg [Ref. 3] corrected for condensate inundation effects on the external heat transfer coefficient with a series of emperical relations. He created a flooding factor F using the following relation:

$$F_n = .6F_d + (1 - .5647\ F_d)\,n^s \qquad \text{(eqn 3.1)}$$

where F_d is a constant indicating the effect of tube spacing and orientation on condensate side drainage. With closely packed tubes, significant side drainage can occur in low velocity steam flow. Condensate generated on tubes above may, due to surface tension effects, proceed laterally to adjacent tubes rather than down. Thus F_d tends to approach 1.0 for closely packed, staggered tube bundles and zero for disperse bundle layouts. S is a constant ranging in value from:

$$(.07 < S < .25)$$

If the condensate rain is acting under the influence of gravity alone S approaches 0.25. But the influence of any steam velocity present begins to alter the rate and direction of condensate flow and correspondingly decrease S. Thus S is a function of vapor velocity and directon, as well as bundle geometry.

The condensate film coefficient for the average tube in the n-th vertical row is then calculated from the uncorrected heat transfer coefficient, h_o, as follows:

$$h_n = [nF_n - (n-1)F_{n-1}]\, h_o \qquad \text{(eqn 3.2)}$$

It is obvious that the determination of a corrected heat transfer coefficient is highly dependent on the choice of S an F_d in equation 3.1. S and F_d are extremely subjective constants and there does not exist a current analytical expression to determine them. Yet the choice of these constants can have profound impact on the condenser design. In CONDIP, as in ORCON1 [Ref. 2], the following, relatively conservative values for S and F_d were used:

$$S = 0.2$$

$$F_d = 0.5$$

An additional important contribution to the external film coefficient is the effect of velocity shear forces on the condensate film. Fujii [Ref. 4] developed the following experimental correlations to correct the Nusselt number for the effect of velocity shear:

$$[Nu_m/Nu_o] = c_1 Nu_o^{(4a-1)} Re_L^{(.5-2a)} \qquad \text{(eqn 3.3)}$$

where Nu_m is the mean Nusselt number, Re_L is the two-phase Reynolds number (based on vapor velocity, tube outside diameter and kinematic viscosity of the condensate) and Nu_o is the standard Nusselt number for the zero shear case. The empirical constants c_1 and a lie within the following ranges:

$$1.13 < c_1 < 1.24$$
$$0.196 < a < 0.2$$

depending on how tube thermal conditions are described. In CONDIP the values for c_1 and a were:

$$c_1 = 1.24$$
$$a = 0.2$$

It should be noted that equation 3.3 is only valid in the range:

$$3.3 < (Re_L/Nu_o) < .28.$$

For smaller values of this parameter Fujii recommends the use of a slightly reduced value of the standard Nusselt number:

$$Nu_m = 0.96\ Nu_o \qquad \text{(eqn 3.4)}$$

It is apparent that the vapor velocities commonly encountered in naval condensers can have an impact on the heat transfer coeffcient.

B. CODE DEVELOPMENT

Johnson [Ref. 5] attempted to couple OPCODE2 (his version of ORCON1) with the optimizer CONMIN, but with little success. There were several reasons for this.

ORCON1 uses iterative techniques to solve for such quantities as condensate rate, steam mass flow rate and steam pressure through the sector. If unrealistic values are encountered, such as negative pressures or steam flow, or if the final steam exit-fraction exceeds a predetermined value, ORCON1 stops the analysis, returns to the beginning of the program and changes certain initial input parameters. The analysis begins again and the process is repeated until a satisfactory design is achieved. Thus ORCON1 has a limited capability to make design decisions to obtain a feasible design.

CONMIN, as do most optimizers, requires complete control in determining all iterative design variable values. As explained earlier, it uses perturbation techniques to calculate gradient information for each design variable and active design constraint, which it then uses to determine search directions. A perturbation of the design variable by CONMIN requires a complete, once-through analysis. If ORCON1 is coupled with CONMIN then any adjustment by ORCON1 will yield false gradient information to the optimizer and hinder, if not completely prevent, CONMIN from arriving at the optimum design. During program development it became apparent that the two programs were working independently against each other and that in its present state ORCON1 was incompatible with CONMIN.

In the formulation of CONDIP, it was necessary to locate and neutralize all the places where such design decisions are made. By removing the ability for CONDIP to make any design decisions it became totally passive and dependent on CONMIN for design variable changes.

However, once this was accomplished, another problem area was discovered. In the ORCON1 code and subsequently in CONDIP there are numerous thermal process and properties calculations that use logarithmic functions and other mathematical relationships which could produce singularities if the variables in the arguments approach zero or are negative. For example, saturation steam temperature is calculated from steam pressure using a logarithmic relationship. If, during a design analysis, saturation pressure approaches a negative value, this represents a clear violation of physical realities and of the limits of that property. Yet a computer cannot make that distinction so it tries to calculate the corresponding saturation temperature which, because of the logarithmic relationship, would be undefined. As just explained, ORCON1 with its built-in decision capability simply starts over when this situation is encountered. But CONDIP, being completely dependent on CONMIN for design decisions, does not have that capability. Remembering that CONMIN requires a complete once-through analysis in order to collect enough information to make a design decision, it was necessary to somehow bypass such mathematical instabilities in order to keep the program operating. Yet the analysis still had to yield reasonable results from the given design in order to obtain meaningful gradients. This prompted the formulation of mathematical relationships to create "penalty" constraints which, if properly written, would indicate to the optimizer that a function or thermal property has violated its physical limits. However, not only would penalty constraints have to be defined, but a "fix up" or "correction" of the violated property or variable would be required in order to allow the analysis to continue. A good physical understanding of the inter-relationship between condenser parameters and the thermal processes resulting from the condenser design is

necessary so that the "fix up" of the violated property would still yield fairly accurate condenser information on which CONMIN could base its search for the optimized design.

For example, a condenser is usually designed around a given steam load. If the condenser has too many tubes, is too long, or coolant flow is too great, then the condenser will be overdesigned. There will be dry tubes within the condenser as all the steam is condensed before steam flow reaches the inner void. In CONDIP this means that zero or negative steam flow will be encountered in the analysis.

If, on the other hand, tube surface area is too small, coolant flow is inadequate or the condenser tube spacing is too tight and is choking the steam flow, then one of two things will happen. Either a quantity of uncondensed steam will make it completely through the condenser, or steam pressure loss in the condenser will cause steam pressure to drop below zero. In addition, there are two reasons why all the steam might not condense. It could be simply due to insufficient heat transfer surface area or it could be because the saturation temperature of the steam has dropped below the coolant inlet temperature. If the latter situation occurs, then there is no driving force for heat to transfer from the steam to the coolant. There is only one way that this situation can occur: if steam saturation pressure drops below some value indirectly determined by the coolant inlet temperature. In any event this condenser is certainly underdesigned and not capable of supporting the required steam load.

As stated earlier, the purpose of optimization is to obtain the best, feasible design. Thus, an understanding of the relationship between the physical characteristics of a given design and the subsequent thermal performances will certainly help in defining the appropriate penalty constraints and their corresponding limits. It will also

aid in the determination of appropriate "corrections" when those limits are violated. It is important to note that with the introduction of these penalty constraints, the definition of a feasible design is revised. A feasible design is now defined as one in which thermal properties and functions are not allowed to violate their physical limits, as well as other design constraints, anywhere in the condenser.

In CONDIP there are three basic thermal properties which could create the above mentioned problems if they fall below a certain value. They are steam saturation pressure, steam flow and steam temperature. Because of the direct relationship between steam saturation pressure and temperature, it was possible to deal with them simultaneously. The solutions that were developed to overcome the effects of these thermal violations determined the extent which CONDIP would optimize.

1. Steam Flow Effects

One source of mathematical instabilities within the program is if steam flow over the tubes falls to zero or below. It is intuitively obvious that steam flow can not physically fall below zero and that in order to keep the program running the steam flow rate must be kept greater than zero. However, correcting for this alone would certainly alter the results of that particular condenser design, perhaps even imply a feasible design.

To indicate to the optimizer an infeasible design was actually encountered - one in which steam flow had dropped below zero - the penalty function WTST was created. Since the condenser analysis is performed sector by sector and assuming there are J sectors in the condenser, then there had to be arrangements for J penalty constraints. This prompted the creation of the array, WTST(J), representing constraint penalty functions for each sector. The absolute

magnitude of these functions were directly related to both the severity of the steam flow violation and the number of dry tubes remaining in the sector. WTST(J) ranged in value from negative infinity to zero, where a value of zero represented a condenser design in which no flow violations occurred. Thus, WTST(J) were constrained functions whose lower limit was zero. For example, during an analysis, if steam flow was determined to fall below zero, then WTST for that sector would be given some negative value. In subsequent designs, as the number of dry tubes approached zero and better designs were obtained, then the magnitude of the penalty function approached zero indicating no constraint violation.

Since penalty constraints are entirely contrived relationships with no real physical basis, it is desirable to minimize their number to avoid the possibility of sending innacurate signals to the optimizer.

To eliminate the need to use the WTST penalty functions as constraints, the values of WTST(J) were consolidated at the end of the sector analysis into the condenser steam exit-fraction constraint. Normally, steam exit-fraction ranges from zero to one and is simply equal to:

$$\frac{\text{steam leaving the condenser}}{\text{steam entering the condenser}}$$

By incorporating the WTST violations into steam exit-fraction, the exit-fraction was made a continuous function ranging in value from negative infinity to one. The negative steam exit-fraction represented a partially dry condenser and its magnitude was in direct proportion to the number of dry tubes. Thus instead of having to evaluate and calculate gradients for J number of WTST(J) contraints, the optimizer simply had to evaluate a previously defined and now expanded exit-fraction constraint.

It should be stressed that making steam exit-fraction continuous through zero was equally as important as eliminating the need for additional constraints. It can be reasonably assumed that for all practical condenser applications, exit steam fraction will always be limited to some positive number near zero. Here is where one applies the physical knowledge of the condenser and its relation to the thermal property of steam flow. As explained earlier, dry tubes represent an over-designed condenser. Thus the natural tendency is for the optimizer to alter those design variables so as to create a more compact condenser. As this occurs, steam exit-fraction will naturally increase. The upper active limit of that constraint will determine the optimum feasible design. While it is not necessary to have a lower limit for steam exit-fraction, it is very important for it to be a continuous smooth function especially in the region near the upper limit. It is therefore critical to properly define the penalty functions WTST(J) in a way so as to provide a smooth transition from the negative, artificial values of negative steam exit-fraction to the real, positive values.

Since the steam flow penalty functions will not be used as constraints, the analytical results will provide gradient information to the optimizer. However, once steam flow has been determined to fall below zero, steam flow for that first dry row of tubes and all subsequent rows must be fixed up with dummy values to allow the program analysis to continue. How that "fix-up" is accomplished will ultimately determine the search direction for the optimizer.

Physically, once steam flow has gone to zero, there should be no further latent heat transfer, no subsequent condensate production, and further pressure losses should be only due to the flow of non-condensible gases. It is necessary to make the computer generated analysis reflect as

closely as possible these physical realities. Since the optimizer no longer has the penalty functions to use in calculating a search direction, other constraint values obtained from the analysis will dictate the next search direction. Gradients will also be calculated using these results and the determination of the next search direction will incorporate these gradients as well. In the case of negative steam flow, steam flow and condensate production over dry rows were given nominal values which were as small as the computer analysis would tolerate. These extremely small values closely approximate zero steam flow and generate results which resemble physical reality as closely as possible.

The following example is provided to better illustrate the logic used in CONDIP to handle negative steam flow. CONDIP determines flow rate through each row in each sector. During a sector analysis, CONDIP calculates the condensate generated at a given row and subtracts that value from the steam flow entering that row to calculate the steam leaving. The exiting steam flow rate is then checked to determine whether steam flow has gone to zero. If it has not, then the analysis continues. If it has, then the following two events occur.

The penalty function, WTST(J), is calculated for that sector and dummy values are inserted for steam flow and condensate rate at the row where the violation occurred. For the remainder of the analysis condensate generation and subsequent steam flow calculations are bypassed and the remaining rows in the sector are fixed up with dummy values for steam flow and condensate. The analysis continues utilizing these dummy values in all appropriate heat transfer and pressure calculations. At the conclusion of the sector analysis, the values of the penalty functions, WTST(J), of each sector are incorporated into the steam exit-fraction.

If the analysis revealed zero dry tubes then WTST(J) for all sectors would be zero and the steam exit-fraction would simply be calculated as:

$$\frac{\text{steam leaving the condenser}}{\text{steam entering the condenser}}$$

If, however, dry tubes were encountered in the condenser analysis then WTST(J) of some or all the sectors would be negative and dependent in magnitude on the number of dry tubes in each of the J sectors, as well as the severity of the steam flow violation. Steam flow leaving any sector which has gone dry would be zero and steam exit-fraction would be evaluated as:

$$\frac{\text{steam leaving any wet sectors}}{\text{steam entering the condenser}}$$

plus a weighted value of all the WTST(J) penalty function values. Using the relationships just described, it is apparent that steam exit-fraction: is negative if condenser tubes are dry; approaches zero as the design becomes feasible; and is greater than zero if there is steam leaving the condenser.

2. Steam Pressure and Temperature Effects

The other possible source of mathematical instability occurs when steam pressure falls below some preset limit. If pressure falls to zero, numerous mathematical singularities will be generated. Yet, before this situation can occur steam temperature will have already fallen below inlet coolant temperature causing singularities in the log mean temperature difference (LMTD) heat transfer calculation. Thus, the lower pressure limit which cannot be physically exceeded is not zero but the minimum saturation pressure established by the inlet coolant temperature. In CONDIP, this lower limit is given the variable name, PTLIM.

As steam flows through the condenser, pressure continually decreases due to friction losses and therefore, it is evaluated at each row in each sector. When the steam saturation pressure drops below PTLIM, indicating a physical violation of realistic limits, then the creation of a penalty function and a corresponding "fix up" of saturation pressure is required to allow the program to continue. The treatment of the problem was therefore analogous to the previous situation dealing with negative steam flow.

PTST(J) was the penalty function devised to indicate to the optimizer that the pressure limit, PTLIM, was violated in any of the J sectors. Values of these constraints ranged from negative infinity to zero, depending on the degree and location in the condenser of the violation. Since pressure is calculated on a row by row basis in each sector, the magnitudes of the pressure penalty functions were directly dependent not only on how much the calculated pressure dropped below PTLIM, but also on the number of rows remaining in the sector. Thus, as the condenser approached a feasible design the PTST(J) consraint values approached zero, indicating lessening violation of the minimum pressure.

As emphasized earlier, it is important to minimize the number of constraints, not only to avoid the possibility of sending confusing signals to the optimizer but also to reduce cost and improve program efficiency. This was accomplished here by inserting dummy values not only into the violated pressure variables but also associated thermal properties such as condensate generation, heat transfer coefficients and heat transfer rates for the row where the violation occurred and all subsequent rows in the sector. The dummy values were chosen such that realistic gradient information would be sent to the optimizer. The proper choice of "fix-up" values for these varaiables resulted in

the elimination of penalty functions as design constraints, and provided sufficient information to determine subsequent search directions.

It is necessary to understand the influence that steam pressure and temperature exert on the overall condenser analysis. With this knowledge it will be easier to predict the physical designs which could cause violations of the pressure limit. PTLIM is violated due to excessive steam flow pressure losses. As explained earlier, these large pressure losses would result from large steam velocities that are found in condensers which are too tightly designed. Thus, the particular condenser design is incapable of handling the required steam load, implying an infeasible design. Understanding this relationship will aid in choosing the appropriate "fix-up" values which will indicate to the optimizer that when the pressure limit is violated an infeasible condenser has been designed.

Physically, When steam temperature falls below coolant inlet temperature (PTLIM is violated) there is no heat transfer from the steam to the coolant and no additional steam is condensed. These physical realities must be reflected in the condenser analysis. Therefore, in subsequent rows, condensation and heat transfer rates were set equal to zero. Since there is no further condensation, the steam exit-fraction is equal to the steam flow at the point of violation divided by the total flow into the condenser. Thus PTLIM indirectly determines the exit steam fraction of the infeasible design. This relationship between exit-fraction and the PTLIM violation is what makes the penalty constraints obsolete. If PTLIM is violated early in the steam's passage through the condenser, steam exit-fractions will be large, violating its upper constraint limit and thus reflecting an underdesigned condenser. As the condenser design improves, then exit-fractions will decrease.

Physically, this can only be accomplished if the condenser design "opens up", reducing pressure losses in the condenser. Consequently, as condenser designs become larger, steam exit-fractions decrease and the condenser is driven towards a feasible design.

The following example illustrates the logic employed by CONDIP to handle steam pressure and temperature violations within the analysis. Condenser inlet flow is divided by the number of sectors in the condenser. Condenser inlet saturation pressure is determined by the steam inlet temperature. Entrance pressure losses are calculated and subtracted from the inlet pressure. The resulting pressure is checked against PTLIM and a violation at this point indicates a totally infeasible condenser in which no steam is condensed. Steam exit-fraction will thus be equal to one. If the saturation pressure is greater than PTLIM the analysis continues row by row through the sector. Pressure losses over each row are calculated and subtracted from the row inlet pressure to determine pressure into the next row of tubes. If this next-row steam pressure is determined to fall below PTLIM, then a thermal violation has occurred requiring "fix up". Subsequent rows are made to indicate zero condensate generation and zero heat transfer. Steam flow over the remaining rows is maintained at a constant value, which will subsequently be used to determine steam exit-fraction. Pressure variables over the remaining rows are given small positive values just large enough to allow the analysis to continue. Although all heat transfer and condensate calculations will be bypassed, the analysis must be allowed to continue so that pressure losses will continue to be calculated based on the steam flow at the point of violation. This is important since steam flow adjustments to the sectors are based on certain pressure comparisons between the sectors. The cumulative sum of all row pressure losses

in each of the sectors must be equal to within some tolerance. If they are not then steam flow into each of the sectors is altered so that the exit pressures from each sector converge to some common value. Thus, an accurate reflection of true pressure losses is important to this calculation.

The value of the steam exit-fraction is again determined to be the single constraint necessary to drive subsequent condenser designs to a feasible optimum configuration. The pressure penalty constraints proved to be superflous information, but the corresponding variable "fix-up" was critical in the determination of search direction.

C. LIMITATIONS

During the development of CONDIP, it became apparent that steam exit-fraction would become the key constraint during optimization of any objective function. A feasible design implies that steam exit-fraction is a small positive number perhaps somewhere between zero and 0.1 percent. As explained earlier, violations of either steam flow or pressure physical limits resulted in penalty functions and variable "fix-up" which were later directly or indirectly incorporated in the calculation of steam exit fraction. Thus any feasible design, let alone the optimum one, centers on the limits placed upon this design constraint. Any number of design variable combinations will yield a feasible design, and each design variable affects steam exit-fraction differently. The intertwined, complex calculations used to ultimately determining exit-fraction are done by sector and row with each design variable repeatedly playing a factor. For example, the profound effect of both vapor shear and condensate inundation on the shell-side heat transfer coefficient and consequently steam exit-fraction, is

indirectly determined by numerous design variables. However, their effects are impossible to predict. The cascading effect of the thousands of calculations performed during the course of a design analysis is to ultimately create a single, highly non-linear variable in the form of the steam exit-fraction, upon which design decisions will be made.

As more design variables were involved in the analysis, the optimizer had difficulty determining their often conflicting effects on both the objective function and the steam exit-fraction. A small perturbation of each of the design variables independently would yield gradients indicating design improvement. But when these gradients were evaluated simultaneously to actually determine the direction of the subsequent design, their combined effect would actually indicate either no improvement of the objective function or a violation of the steam exit fraction design constraint. The end result would be that the optimization process would stall as no feasible search direction could be obtained. Larger perturbations to the design variables were required to properly evaluate their relative effects on the objective function and any active or violated constraints. This would enable the optimizer to overcome either small inconsistencies or discontinuities in the objective function and the constraint functions which would otherwise prevent the optimizer from reaching the optimum design. This was accomplished during data input by changing the normalized finite difference step from 0.01 to about 0.1. Increasing the finite difference is not without its drawbacks. As the optimum objective value is approached, the optimizer overlooks the subtle effects of small changes in the design variables because of the relatively large perturbations. Thus, depending on the initial design variables, the optimizer will improve the design to some point near, but necessarily at, the optimum.

When a design becomes feasible, steam exit-fraction will always become an active constraint. But the stated goal is not in achieving a feasible design but in driving the design to a feasible optimum. However, this iterative process can not be accomplished at the expense of violating a constraint and it was here that further complication was introduced. The initial impetus in any optimization process is to first obtain a feasible design. However, once the very small steam exit-fractions are obtained that are necessary for a feasible design, the exit-fraction becomes extremely sensitive to any further design variable changes. Thus any effort to further improve the current design could easily cause exit fraction to increase. Even slight increases would be perceived as violations of the constraint limit and thus prevent further optimization from the first feasible design. There are two possible solutions to this problem. Either increase the upper limit on the exit-fraction constraint or redefine the constraint. COPES formulates the general constraint function in such a way as to allow the user to increase the active region about the constraint limit. This is accomplished here by increasing the normalization factor in the following expression for the exit-fraction constraint function:

$$\frac{BU - EXITFR}{SCAL1} \leq 0.$$

where BU is the upper constraint bound, EXITFR is the exit-fraction constraint value and SCAL1 is the normalization factor for this constraint. Increasing the normalization factor reduces the optimizer's sensitivity to constraint violations by enlarging the range of constraint values in which the constraint is active. This enlarges the region of feasibility and allows the optimizer more flexibilty in altering design variables by reducing the risk of violating

the constraint. The overall effect is that the design optimization can continue but at the expense of accurate constraint limits. The normalization factor used effectively for the exit-fraction in CONDIP analysis was approximately 0.1.

One of the stated objectives was to create a robust program which would consistently yield the single best optimum design independent of the initial design and not get hung up on a relative optimum. As it was explained earlier, although relative optimums represented design improvement, they also indicated the inability of the optimizer to locate the single best or true optimum design. However, the objective was achieved for only three design variables. When more than three design variables were used, the optimum designs became loosely dependent on the initial input, although not in any predictable way. This is not to say that the condenser design did not optimize. By incorporating the finite difference and scaling normalization on exit-fraction as described above, final designs did yield objective function values which were continually within about ten percent of the true optimum regardless of the initial design. However, there was just no guarantee that the single, best optimum design could be consistently obtained. In summary, the reasons why CONDIP did not consistently optimize to the single, true optimum were: the extreme non-linearity of the steam exit-fraction, the need for a large finite difference gradient, and the need for a normalization factor for the exit-fraction upper limit constraint.

While the optimum design solutions obtained from CONDIP may be sufficient, there are several ways to improve the results and increase the chances of obtaining the best possible design. The easiest way is to try several initial input values until the user is satisfied that the best solution has been obtained. The problem with this approach is

that it is both costly and time consuming. A second recommendation is to couple an extremely simplified version of the condenser analysis with the optimizer to obtain a educated guess as to what the optimum design should be. The results of this analysis could then be used as input for CONDIP. OPCODE1, which utilizes the HEI methods in its analysis, is a likely candidate. The advantage of this approach is that a quicker, cheaper analysis can be used to obtain a rough idea of the anticipated optimum design. CONDIP can then use these design results to obtain even better and more accurate solutions, faster. There is still no guarantee, however, that the true optimum will be solved. Perhaps with the development of more robust and versatile optimizers, ones which uses numerical techniques and methods that are better suited to this type of problem than CONMIN, more precise solutions can be obtained. However, there is little more that can be done to simplify the analysis of the steam exit-fraction and subsequently linearize the problem.

IV. DESCRIPTION OF THE MAIN AND SUPPORTING SUBROUTINES

A. MAJOR SUBROUTINES

The following section contains a brief description of the major subroutines in CONDIP. The appropriate flow diagrams are also provided to better illustrate and complement the explanations. For further information concerning the various subroutines and functions see the CONDIP listing in Appendix C and ORCON1 [Ref. 2].

1. ANALIZ

This subroutine basically arranges CONDIP in a standardized form which is compatible with COPES/CONMIN. COPES uses a variable flag, ICALC, to coordinate the optimization process with ANALIZ. Utilizing this flag ANALIZ then calls the input, analysis and output portions of CONDIP as required. When COPES sets ICALC equal to one ANALIZ reads in all initial input. This is the only time any input can be entered. When ICALC equals two, COPES works with CONMIN to optimize the design. ANALIZ makes available the analysis portion of the program to be used repeatedly by CONMIN. When COPES sets ICALC equal to three, the optimization is complete and ANALIZ calls all applicable output subroutines. Figure 4.1 illustrates the flow process for ANALIZ.

2. INPUT

This subroutine enters all initial input of data by which the initial design is determined. The resultant design may be either feasible or infeasible, subject to the limitations previously discussed, so it is not critical what values are initially assigned to the design variables.

However, the initial input is screened to prevent the introduction of totally unrealistic values of variables into the program. For example, initial tube thickness, tube inner diameter, tube number and tube length are all checked to ensure that their values are greater than zero. If any of the screened initial inputs do not satisfy the minimum requirements, then the program exits prior to entry into the optimizer. The limits of the design variales and constraints will prevent similar situations from occurring during the analysis. Figure 4.2 presents the flow diagram for the INPUT subroutine.

3. OUT3

This subroutine simply prints all the initial values entered in the INPUT subroutine.

4. ORCON

This subroutine calculates the bundle geometry, flooding factors and such coolant flow parameters as pressure loss, flow rate, and pumping power. There are two options available to determine bundle geometry, each with certain advantages and disadvantages.

Option1: The number of rows is entered as a constant and the tube number is determined based on pitch, tube outer diameter, and row spacing. The advantage of this method to determine bundle geometry is that it allows the user to linearly vary pitch and/or tube inner diameter by row. The disadvantage is that tube number is a dependent variable. The optimzer is therefore limited in determining the optimum design by the specified number of rows.

Option2: The number of tubes can be used as a design variable while the number of rows is determined by tube number, row spacing, pitch and tube outer diameter. There

is more flexibility in this method of condenser design but it is not possible to linearly vary tube pitch and inner diameter. The condenser bundle is generated from a specified inner void out, and all the appropriate condenser geometry is determined for one of the identical 30 degree sectors. Overall bundle volume is then calculated as is the ratio of tube hole area to tube sheet area.

Once the basic condenser geometry has been determined, the code then proceeds through an algorithm to calculate baffle location based on an input value specifying the number of baffles desired in the condenser bundle. After this has been completed, flooding factors are determined. That is, the number of tubes in a vertical row above the central tube in each row is calculated. This is done for each of the six sectors on one side of a circular bundle. Symmetry is assumed for the other side. These flooding factors are later used in calculations to determine the effect of condensate inundation on shell-side heat transfer coefficients.

Finally, ORCON calculates coolant mass flow, coolant velocity, header pressure difference and pumping power based on the type of coolant flow input received. The flow chart in Figure 4.3 is a simple illustration of the logic used in ORCON. From ORCON, the subroutine SECALC is called.

5. SECALC

This subroutine determines all the parameters of each of the sectors in the condenser by row. The first calculation made in SECALC is the determination of the cooler geometry, if there is one. Entrance pressure losses into the condenser bundle are calculated for each sector and saturation pressure is checked to ensure that it is greater that PTLIM. From this point, much of the remaining

subroutine is comprised of two do-loops with one nested inside the other. The outer loop cycles through however many sectors are in the condenser model. The inner loop cycles through the rows in the sectors. Pressure, temperature, mixture velocity, steam flow and condensate flow are calculated at each sector row. The subroutine HETTRN is called repeatedly to provide the necessary heat transfer information. Pressure and steam flow is checked continually at each row to ensure that neither falls below its predetermined lower limits. In the event that either situation occurs, the appropriate penalty function and fix-up procedure is implemented to enable the analysis to continue. As previously discussed, these values are chosen to reflect as accurately as possible real conditions which would occur when steam flow or pressure violate their physical limits.

Once all the sectors have been analyzed the cumulative steam-side pressure losses from each sector are compared. Steam pressure at the inner void must be uniform, therefore the sector pressure losses are required to be equal within some allowable tolerance. If they are not, then the distribution of inlet steam flow into each sector is altered to force the pressure losses to converge to a single value. Once steam flow to the sectors has been adjusted, the sector and row analysis in SECALC is repeated until the pressure losses within each sector approach a common value. After the pressure comparison has been satisfied, certain overall condenser parameters are calculated such as steam exit-fraction, bundle heat load, and steam-side pressure drops.

Finally, if a cooler is required, the subroutine COOLEX is called. Otherwise the condenser analysis is complete. The flow diagram for SECALC is presented in Figure 4.4.

6. HETTRN

This subroutine is called repeatedly in SECALC to solve for all shell and tube-side heat transfer properties for each row in each sector of the condenser. In particular, values for the overall heat transfer coefficient and log mean temperature difference are utilized by SECALC in computing condensate production and heat transfer rate at each row of tubes.

On entering this subroutine, a series of estimates for certain row variables are calulated. Based on an assumed initial value for the overall heat transfer coefficient, the exit coolant temperature and corresponding film temperature are calculated. Utilizing these temperatures, the LMTD, thermal resistances, individual heat transfer coefficients and numerous other heat transfer parameters are then calculated. Finally, another value for the overall heat transfer coefficient is determined based on the above-mentioned analysis, and this final value is subsequently compared to the initial value. If they are not in agreement, within a specified degree of tolerance, then the initial value for the overall heat transfer coefficient is updated and the entire process is repeated until the initial and final values converge. This iterative process is necessary as temperature dependent heat transfer coefficients, film temperature drops, and exit coolant temperatures are all being calculated simultaneously.

Note that it is in HETTRN that the concepts of vapor shear and condensate inundation are incorporated. Heat transfer coefficients are corrected for both effects based on the calculations presented earlier. Also note that since steam temperature is never allowed to drop below inlet coolant temperature in the calling subroutine SECALC, resultant LMTD calculations in HETTRN will not yield singularities.

Once all the heat transfer variables have been determined, control is returned to SECALC where the appropriate results are utilized and stored. The appropriate flow diagram for HETTRN presented in Figure 4.5.

7. COOLEX

This subroutine solves for all the necessary parameters required in the cooler analysis. The cooler is assumed to be of rectangular cross-secton with the height of the cooler not to exceed the difference between the condenser inner and outer radii. The values used for tube pitch and tube diameters in the cooler are the same as the innermost row of the condenser bundle.

Steam exits the condenser bundle, collects in the inner void and enters the bottom row of the cooler. The steam then proceeds vertically up through the cooler. The physical location of the cooler is not a prerequisite to the subsequent design, although it is expected that the ccoler will be placed within the condenser bundle, thus the limit on cooler height.

The first calculation in COOLEX determines the steam velocity at minimum cross-secton in the first row of tubes, VLCMAX. VLCMAX is directly proportional to the amount of steam and non-condensible gas entering the cooler as well as the ccoler geometry. Therefore the constrained limits for VLCMAX will play a major factor in the overall condenser design.

Subsequent row analysis is treated identically as in SECALC. However, all pertinent heat transfer data are calculated directly within COOLEX, making it independent of HETTRN. Steam pressure and steam flow are checked at each row to ensure that the appropriate limits are not violated and all thermodynamic parameters are calculated. At the conclusion of COOLEX, cooler performance variables such as

heat load, exit-fraction steam, steam pressure losses and overall heat transfer coefficients are calculated and control is returned to SECALC. The flow diagram for the COOLEX subroutine is illustrated in Figure 4.6.

8. OUT2

This subroutine prints the overall condenser bundle results including heat load, steam exit-fraction, overall heat transfer coefficient, overall condenser LMTD and bundle volume. Normally, OUT2 is called once after the initial design is analyzed and again after the optimum design has been determined. Final design variable values such as tube number, coolant flow, tube pitch, tube wall thickness and tube inner diameter are also printed.

9. OUT2C

This subroutine prints the cooler results as well as the combined cooler/condenser results. This subroutine is called from the subroutine OUT2 and is called only if a cooler is required and subsequently designed. Therefore, these results will always be printed in conjunction with OUT2 output.

10. OUT3

This subroutine prints a very detailed output of the condenser and cooler results by row and sector. Nearly all the thermodynamic and heat transfer properties are presented, thus providing a rather complete picture of conditions everywhere in the condenser. This is extremely helpful in determining, for example, where additional heat transfer enhancement would be most beneficial, or where baffles should be best located to reduce the effects of condensate inundation.

B. SUPPORTING SUBROUTINES

The following is a brief description of supporting functions and subroutines called frequently by the main subroutines.

1. DFSVTY: This subroutine returns the value of the mutual diffusivity of the steam and non-condensible gas present.

2. XTR: This funcion subroutine transforms the calculated data, received in the argument list, to the log values and performs a linear regression on two or more points using the model.

3. AMUFN: This function subroutine calculates the viscosity of the non-condensible gas in lbm/(ft-sec).

4. BMUFN: This function subroutine calculates the viscosity of a saline sclution in the range of 0-24 percent concentration and temperatures of 40-210 °F in lbm/(hr-ft).

5. CPAFN: This function subroutine returns a value for the heat capacity of the inert, non-condensible gas mixed in with the steam in units of Btu/(lbm-mol-°F).

6. CPFN: This function subroutine calculates the specific heat of a saline sclution units of Btu/(lbm-°F).

7. CPSFN: This function subroutine calculates the heat capacity of steam in Btu/(lbm-mol-°F).

8. HPGFN: This function subroutine returns a value for the latent heat of vaporization of water in Btu/lbm.

9. PRSDRP: This subroutine returns the shell-side pressure drop across a row of tubes in psia.

10. PSATFN: This function subroutine calculates saturation

pressure of steam as functicn of temperature. Pressure is returned in units of psia.

11. ROEFN: This function subroutine calculates the density of a saline solution ofconcentration range 0-24 percent and temperature range of 40-300 °F. Density is returned in units of lbm/(cu.ft.).

12. SKBFN: This function subroutine calculates the thermal conductivity of a saline solution of concentration range 0-24 percent and a temperature range of 40-300 °F. Thermal conductivity is in (Btu)/(hr-f-°F).

13. TSATFN: This function suroutine returns the value for steam temperature in °R given a pressure in psia.

14. VGFN: This function subroutine calculates the specific volume of steam as a function of temperature and pressure. It has units of (cu.ft.)/lbm.

15. SWITCH: This function subroutine reverses the order of a stored array.

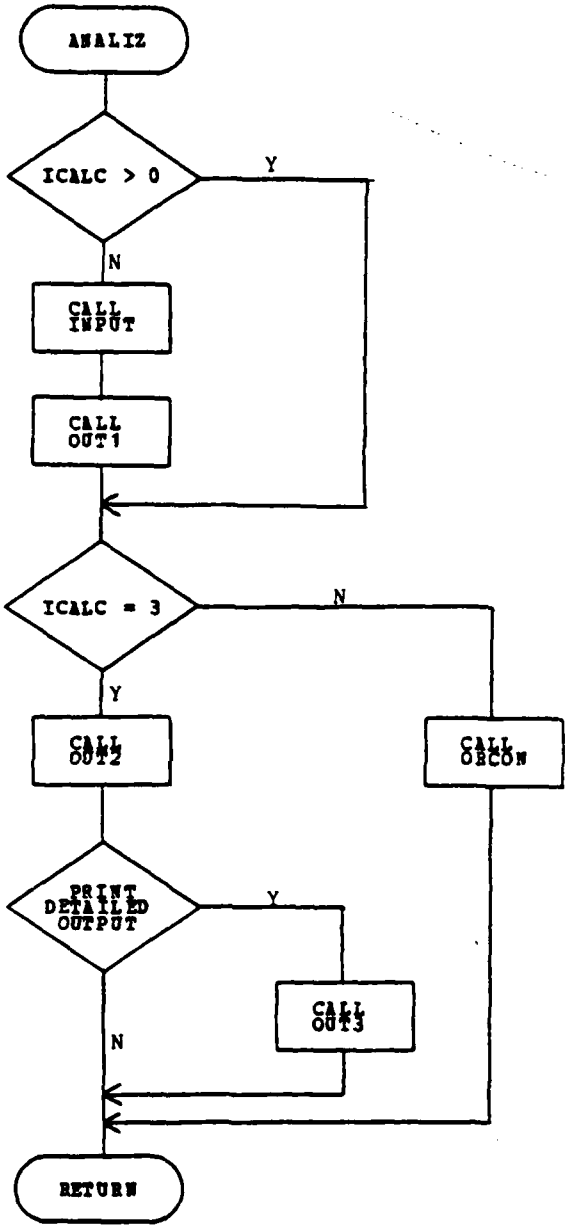


Figure 4.1 Flow Diagram for the ANALIZ Subroutine.

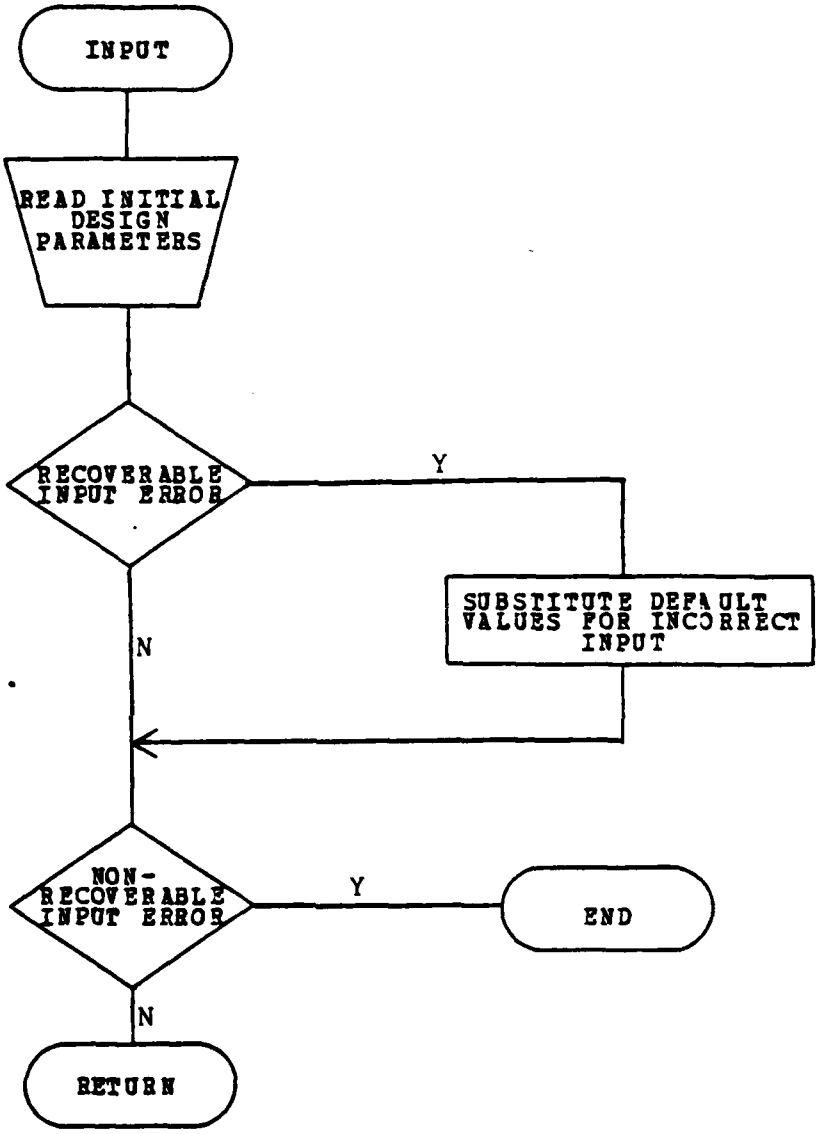


Figure 4.2 Flow Diagram for the INPUT Subroutine.

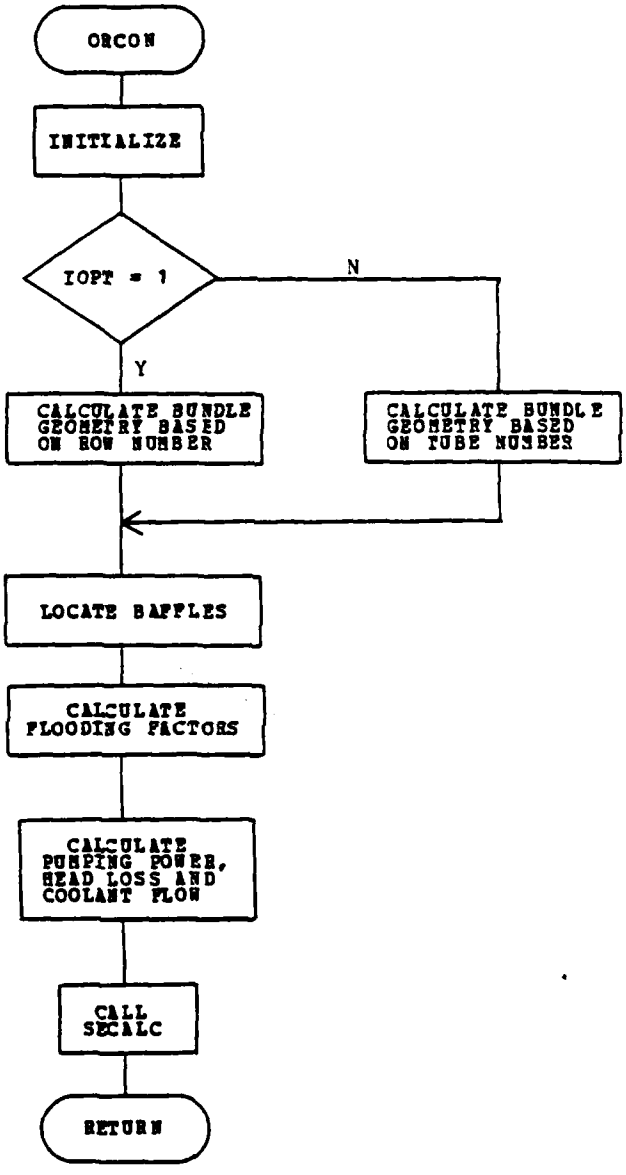


Figure 4.3 Flow Diagram for the ORCON Subroutine.

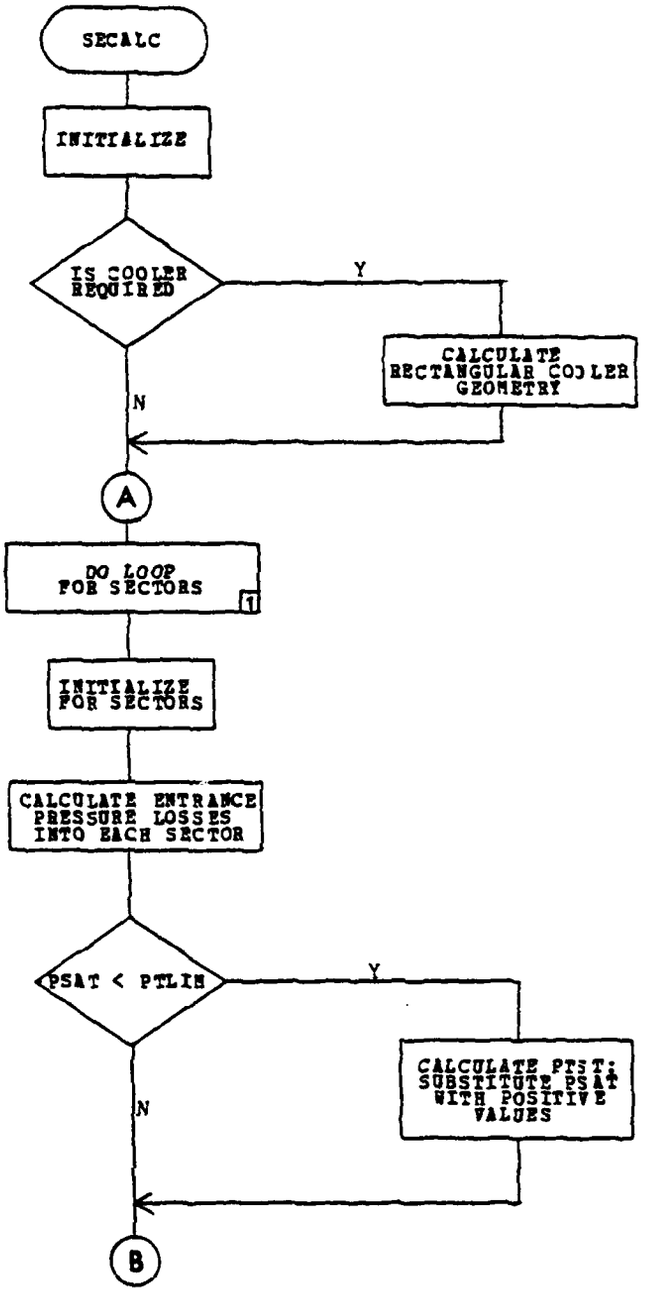
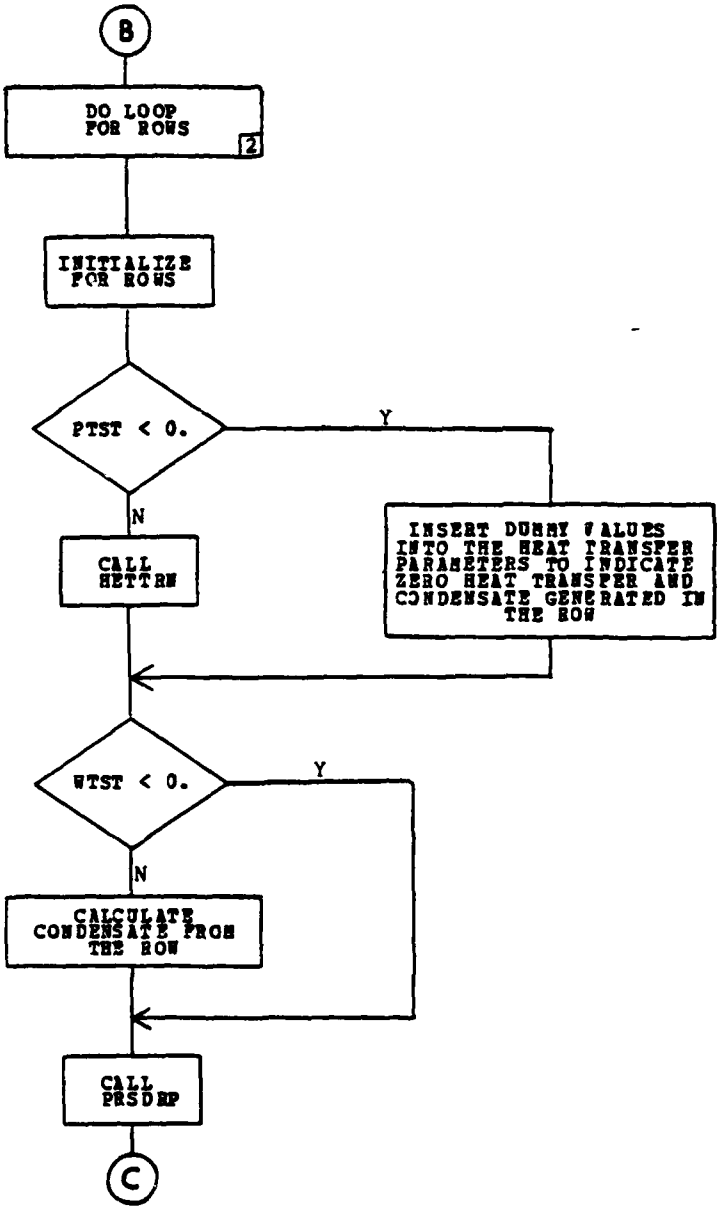
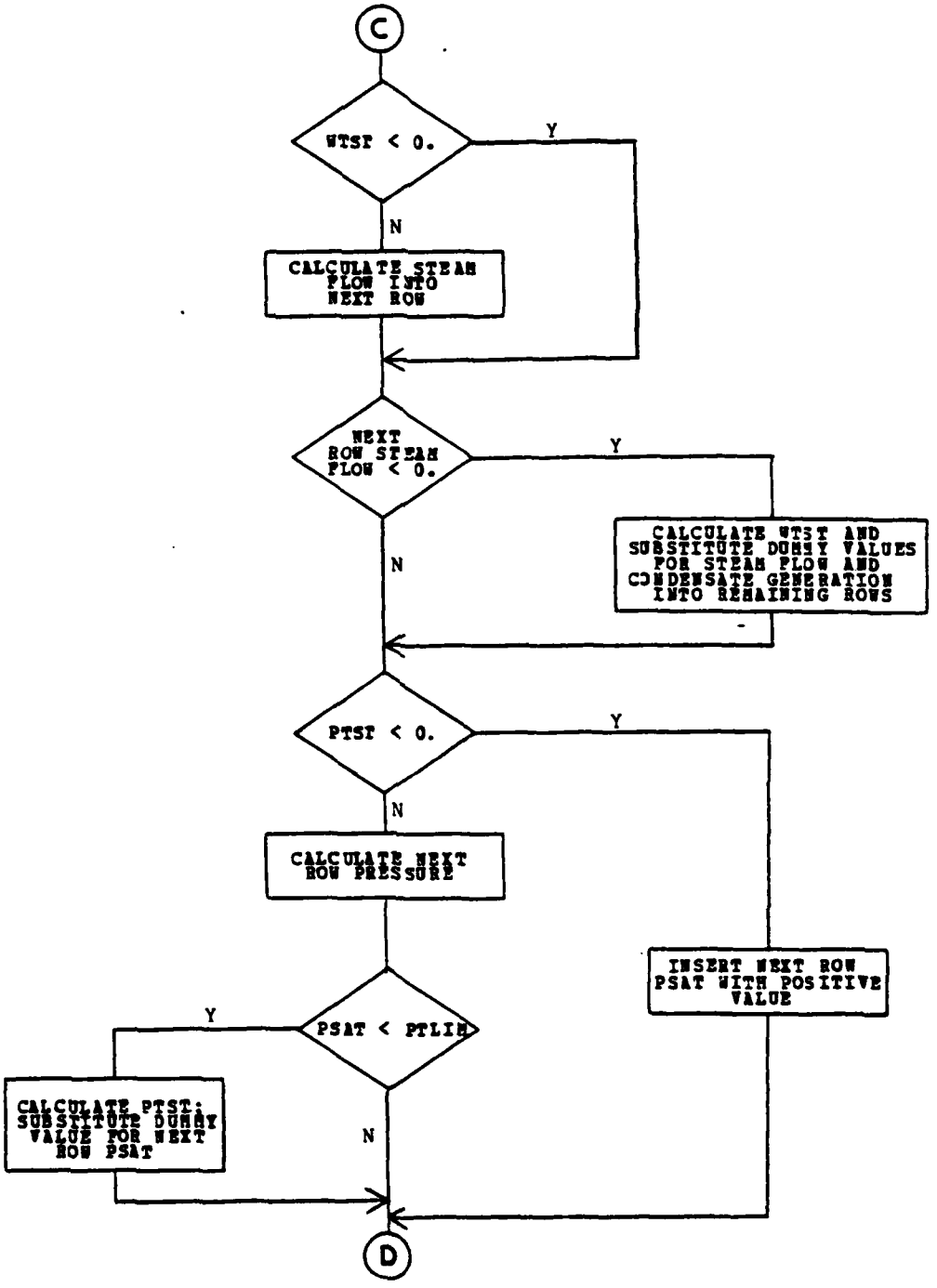


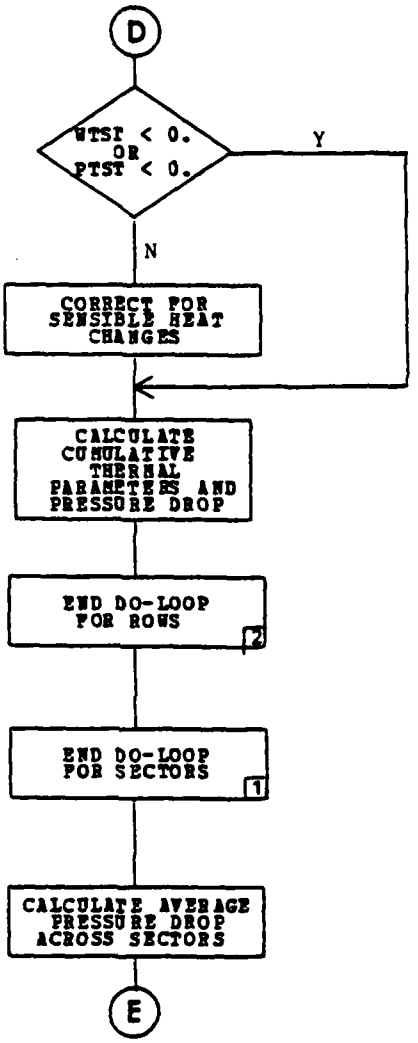
Figure 4.4 Flow Diagram for the SECALC Subroutine.



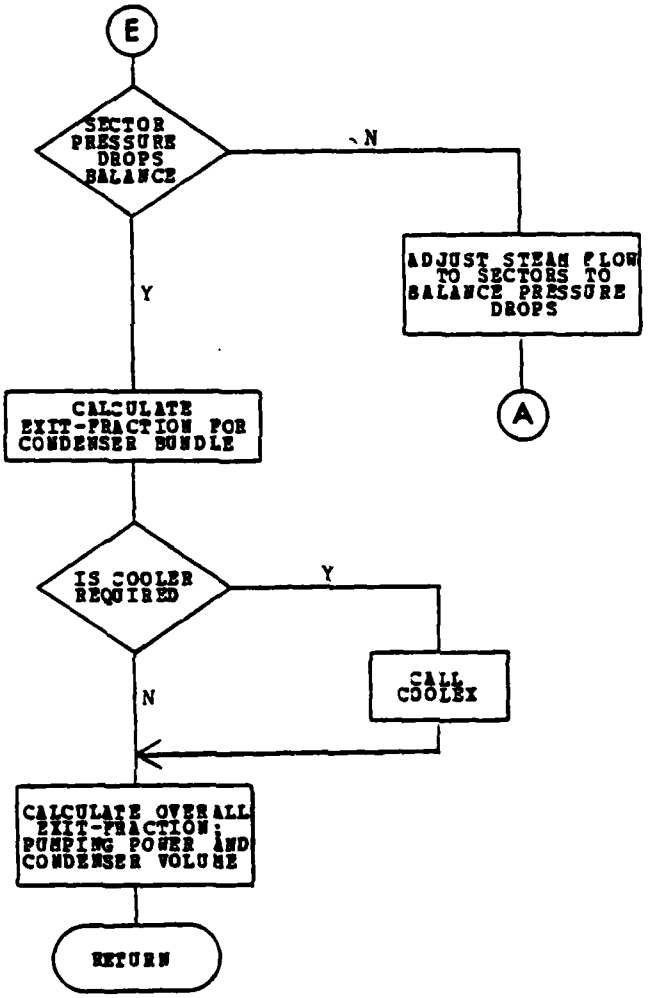
SECALC Flow Diagram (continued)



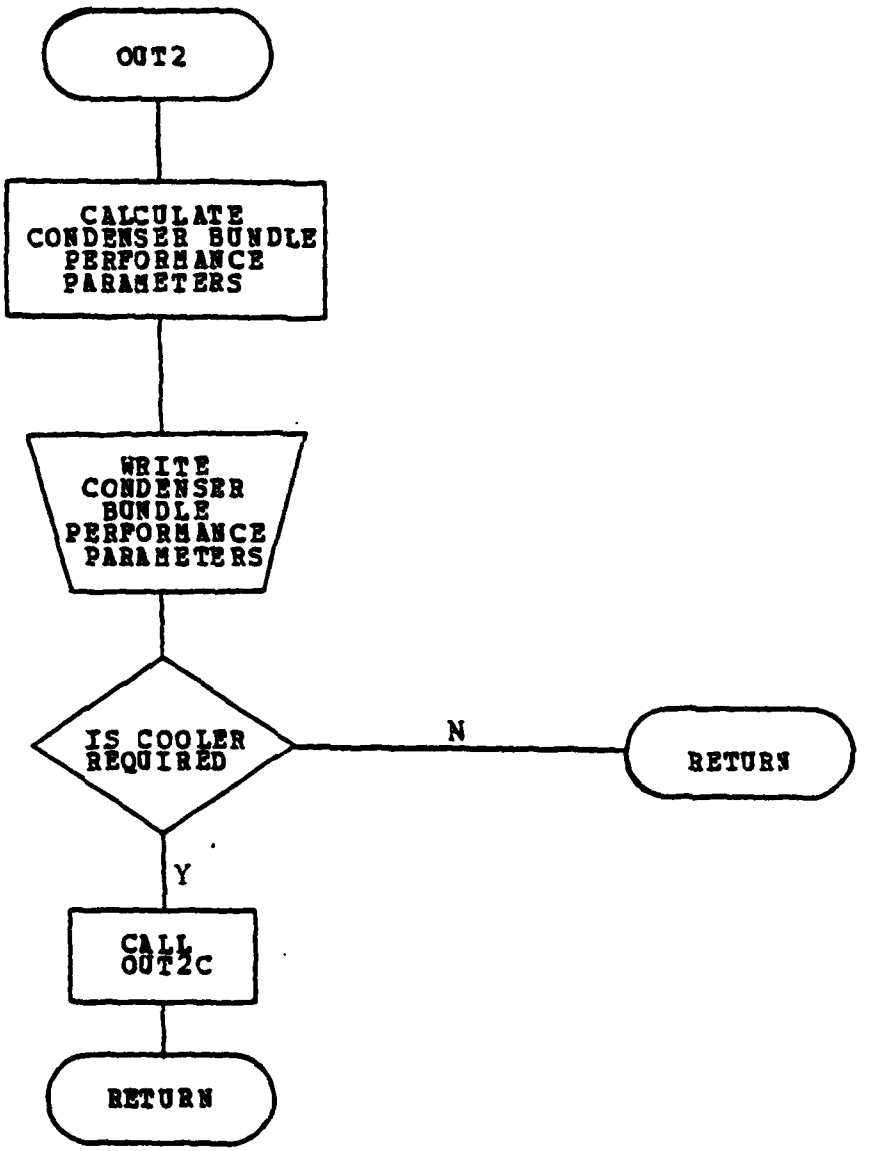
SECALC Flow Diagram (continued)



SECALC Flow Diagram (continued)



SECALC Flow Diagram (continued)



Flow Diagram for the OUT2 Subroutine

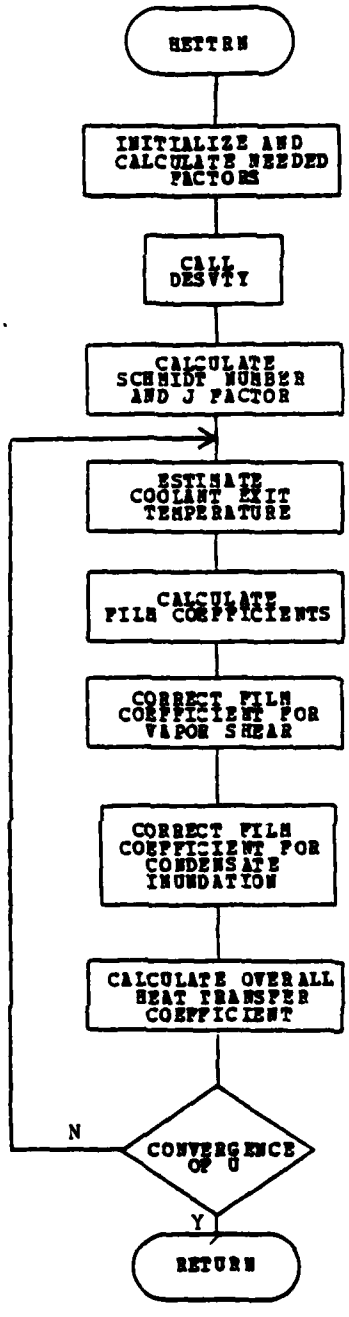


Figure 4.5 Flow Diagram for the HETTRN Subroutine.

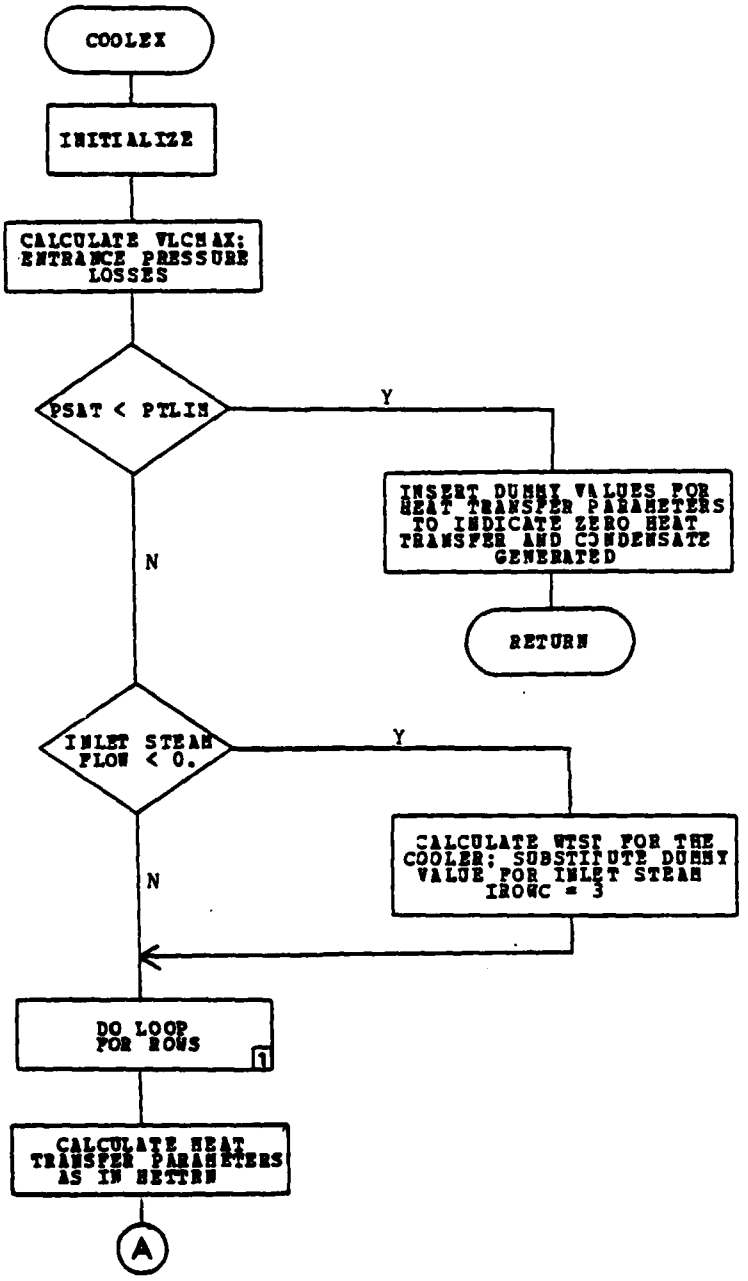
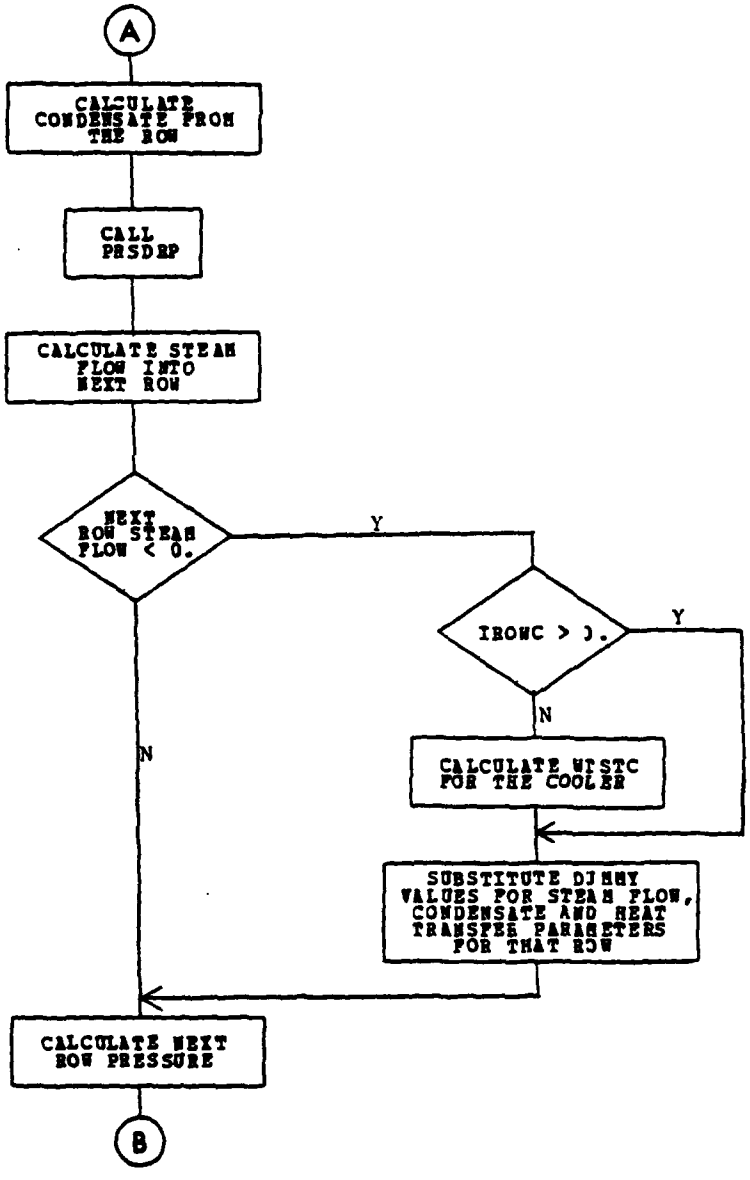
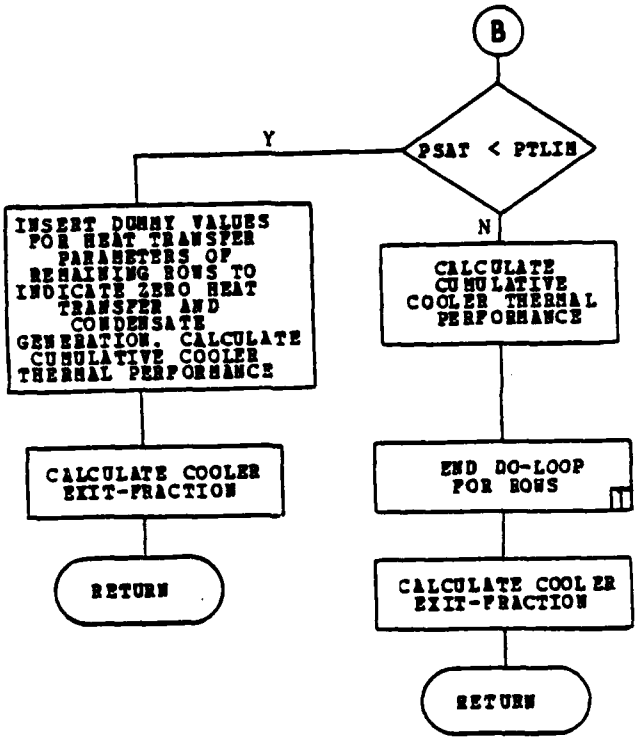


Figure 4.6 Flow Diagram for the COOLEX Subroutine.



COOLEX Flow Diagram (continued)



COOLEX Flow Diagram (continued)

V. RESULTS

A. CONDIP VERIFICATION

It was desirable to verify the single pass capability of CONDIP (i.e. without optimization) as a predictor of condenser performance by comparison with actual experimental data. However, complete and accurate data on condenser design and corresponding performance is not always readily available. Lynch [Ref. 18] encountered this same problem in attempting to verify ORCON1. However, he did manage to locate some actual experimental condenser data, obtained during a test conducted to determine the general performance of the DDG-37 class propulsion machinery [Ref. 16]. The test took place at the Naval Boiler and Turbine Laboratory and was conducted primarily to determine the performance of the turbine and reduction gears. Some limited condenser data was taken as a by-product. The various measurements were obtained as described below:

1. Steam flow measurements were made by weighing the condensate.

2. Cooling water inlet and outlet temperatures were measured by thermometers installed in the inlet and discharge lines.

3. The heat load is calculated based on total steam flow into the condenser multiplied by the difference between inlet steam and condensate enthalpies.

4. Circulating water flow was determined from a heat balance around the condenser. The total heat load was divided by the circulating water heat capacity and temperature rise to obtain flow rate.

5. Condenser inlet pressure was determined by pressure instruments located above the condenser inlet flanges.

6. Non-condensible gas flow was measured by a flowrator.

7. Pressure at the air ejector was measured directly. This pressure and the inlet pressure determined the pressure drop across the condenser.

It should be pointed out that this data were not recorded with the care that normally accompanies scientific data collection. Neither the instruments nor the techniques employed were particularly accurate. The possibility that this observed data are in error casts a cloud over the credibility of the corresponding condenser performance, which was calculated based on those values. However, for a lack of better alternatives, this data and the resulting condenser analysis will be used to determine the reliability of CONDIP.

The DDG-37 condenser geometric design variables obtained from the technical manual [Ref. 15] and input parameters corresponding to a full speed run are presented in Table I. An attempt was made to repeat the design using CONDIP. The results of CONDIP's proposed design as well as the experimental performance are presented for comparison in Table II. Percentages were calculated to quantify the differences between the actual and hypothetical performance.

Before elaborating on the results of this verification, some notable differences between the two designs must be clarified. First, a specific fouling factor was not determined at the time of the experiment and was therefore not provided. A somewhat realistic cleanliness factor of 87.5 percent (fouling factor of .0002) was utilized.

Second, in the DDG-37 condenser the rectangular cooler appears to be inserted directly into the condenser bundle.

However, in order to accomodate the cooler, the bundle must expand or distort. In addition, a void of some dimensions must be provided-for in the center of the bundle to collect any uncondensed steam and non-condensible gases. Diagrams in [Ref. 15] indicate that the DDG-37 condenser is indeed nearly elliptical in shape with bundle axes of 5.67 and 7.17 feet. Although it is apparent that a void does exist, exact dimensions can not be readily determined from the available information.

CONDIP approximates this design by creating separately a circular condenser bundle and a rectangular cooler, the height of which cannot exceed the difference between the outer and inner bundle radii. A circular void of predetermined size is provided-for when determining the condenser bundle geometry. Subsequent volume calculations are performed on the condenser bundle and cooler separately and the overall condenser volume is computed as simply their sum.

Although CONDIP does not exactly duplicate the geometric configuration of the DDG-37 condenser, it was possible to manipulate certain initial design variables in order to cause CONDIP to develop an approximately equivalent configuration. These variables were chosen because, for small changes in their values, there is a rather significant change in the bundle geometry with relatively small effects on the overall condenser performance. Since there are no specific dimensions provided for the inner void in the DDG-37 technical manual, it was picked to be one of the design variables to be adjusted. Row spacing was also adjusted because it satisfied the conditions described above. Through trial and error a combination of row spacing and inner void radius were determined, from which CONDIP yielded a geometric design similar to the DDG-37 condenser and that satisfied condenser requirements specified in

[Ref. 17]. In this particular case, the void diameter and row spacing were determined to be 1.1 feet and 1.35 inches respectively. This arrangement enabled the condenser model to closely approximate the tube sheet area ratio of the actual DDG-37 condenser. This manipulation, however, must be interpreted as another source of error and innacuracy when comparing CONDIP's condenser performance with the experimental results.

Lastly, condenser designs in [Ref. 15] reveal that three different tube patterns were employed in the DDG-37 condenser. In addition, two different values for tube pitch were used - a pitch of 1.4 in the condenser bundle and a pitch of 1.3 in the cooler. This situation cannot be duplicated in CONDIP. Therefore a constant pitch of 1.40 and a uniform tube pattern were utilized throughout the condenser.

The design approximations utilized in CONDIP to try to geometrically simulate the actual DDG-37 condenser introduce significant uncertainty into subsequent design comparisons. This, coupled with the fact that the data collected is also suspect, would imply that it is rather difficult to verify CONDIP's analysis with the information available. It should also be noted that CONDIP is sensitive to even small variance in either the data collected (i.e. steam inlet temperature) or the approximated design variables. However, despite the above-mentioned problems associated with equating CONDIP's condenser to the DDG-37 condenser, the experimental data obtained from the DDG-37 condenser still provide the best available base upon which to make a reasonable determination of CONDIP's capabilities and limitations.

In comparing the results in Table II, it is immediately clear that there is significant difference between certain condenser performance parameters predicted by CONDIP and the corresponding experimentally derived condenser perfcrmance. Already, much has been said about the numerous geometric

approximations used to model the DDG-37 condenser. But questionable data and geometric manipulations may not completely explain the 13 percent exit-fraction and general poor performance generated in CONDIP's analysis. Its values for the average overall heat transfer coefficient and heat rejected were significantly lower than the experimental results. One source of the problem lies in the actual heat transfer analysis performed in the code. Lynch [Ref. 18] graphically illustrated how sensitive this analysis is to the effects of condensate inundation. In particular, by making small changes - within the allowable ranges - in the constants used in Eissenberg's correlations for condensate rain, significant improvement could be realized in the overall heat transfer characteristics of the condenser. CONDIP's results, when compared to the experimental data support the argument that the values currently used in the inundation correlations are rather conservative in nature, and cause the overall analysis to yield a poor preformance for the given steam load and condenser design.

Therefore, in order to present CONDIP with a fair test to determine its credibility as a design predictor, some additional work must be first accomplished. A condenser geometrically identical to the general model created in CONDIP should be constructed with complete and accurate data acquisition systems to establish a thorough data base from which to compare. Also, more research should be performed on the effects of condensate inundation and velocity shear to obtain more precise correlations in determining their overall effects on the film heat transfer coefficients.

One last additional point should be mentioned. In comparing the steam-side pressure drops through the condenser, it was shown that CONDIP's pressure losses were nearly 72 percent larger the the actual physical measurements. However this radical difference is mainly due to the

high pressure losses experienced at the entrance of the cooler as a large volume of steam tried to force its way through the small available area. Therefore, the significance of this large disagreement in results is relatively minor and can be treated simply as a consequence of the more important heat transfer limitations in the comparison run.

Although the goal of verifying CONDIP as a design predictor has proven elusive, it was still possible to demonstrate its capabilities through comparison studies. Therefore, the remaining emphasis in this thesis is to show the ability of CONDIP (in combination with the optimizer COPES/CONMIN) to take an initial design with a given framework of constraints and design variables, and obtain better designs based on a desired objective function.

B. EXPLANATION OF THE CASE STUDIES

The following case studies were devised to best exercise the capabilities of CONDIP. They were made as realistic as possible so as to simulate the problem of condenser design and specification confronting the engineer during the early stages of power plant design. The condenser performance returned by CONDIP during the verification run and contained in Table II will serve as a baseline for comparing the results of each case study. The baseline condenser performance is based on the design parameters from the DDG-37 condenser listed in Table I. It was stated earlier that CONDIP's optimization results are slightly sensitive to the initial design if more than three design variables are used. Since all the cases involve eight or more design variables it would be best, for the purposes of comparison, to start from the same initial design in all cases. Therefore, the initial design variables used for the verification run and contained in Table I will be utilized as the baseline

design. Although many of these initial design variables will be allowed to change during optimization, certain basic condenser requirements will not. They include: steam flow into the condenser, inlet steam saturation pressure and temperature, cooling water injection temperature, the fraction of non-condensible gases in the steam, the tube fouling factor, and the tube material. It should be noted that although there was an initial value for row spacing given in Table I, row spacing was not used as a design variable during any of the optimizations. Instead, the program used the default method of row spacing calculation available in the code where the rows are spaced such that a 60-degree equilateral triangle pattern of concentric rows is obtained. Row spacing is therefore dependent on tube pitch and tube outer diameter by the following relation:

$$RSPA = (SDDO * ODOI) * .866 \qquad \text{(eqn 5.1)}$$

where RSPA is row spacing, SDDO is tube pitch, and ODOI is tube outer diameter in inches.

There are a few key points to be kept in mind when comparing the results of the case studies with the baseline. First, the baseline design is an infeasible and inadequate design. Its performance indicates that it is not capable of supporting the required steam load by returning a steam exit-fraction in excess of 13 percent. So any gains in the objective function that were realized in the case studies is even more remarkable since it is a necessary condition that the optimum design be a feasible design, defined as having an exit-fraction not greater than 1 percent. Second, the percent change referred to when analyzing the results is calculated based on the baseline design. Thus the baseline serves as a uniform frame of reference. Next, it should be noted that because of the large number of design variables

and constraints, intuition on how an optimized result will turn out is not always applicable. Finally, it will be easier to understand the effects of the various design parameters by keeping in mind the following, very basic, heat transfer correlation:

$$Q = U * A * LMTD \qquad \text{(eqn 5.2)}$$

where Q is the rate of heat released as the steam condenses; U is the overall heat transfer coefficient; A is the heat transfer surface area; and LMTD can be interpreted as the thermal driving force between the steam and the coolant. Q is directly dependent on steam flow and pressure into the condenser, the percentage of that steam that is condensed, and any subcooling of the condensate. For a given steam load and a very small exit-fraction Q is nearly constant as the optimized results in all the case studies will indicate.

1. Constraint Framework for CONDIP

In order to simulate an actual trade-off study, the constraints and their respective limits were kept constant for all the case studies. The condenser was to be designed with a maximum bundle diameter of ten feet, a maximum and minimum tube outer diameter of 0.625 and 1.25 inches respectively, a steam exit-fraction of not more than 1 percent, a maximum cooler inlet velocity (VLCMAX) of 200 feet/second, and a ratio of tube sheet hole area to total tube sheet area of less than 0.30.

The constraint on bundle diameter was chosen somewhat arbitrarily. It seems unlikely that this limit would be realistically exceeded, although certainly space requirements would dictate the exact configuration. Tube outer diameter is dependent on the values for tube wall thickness and tube inner diameter. Thus the limits imposed on tube

outer diameter represent realistic restrictions on the possible cobinations of inner diameter and wall thickness. These restrictions are based loosely on anticipated tube structural and strength requirements and correspond to values of normally available tubes [Ref. 19]. The maximum limit of 200 feet/second for VLCMAX was also a somewhat arbitrary but realistic limit. It is assumed that steam velocities often exceed that value in the condenser bundle.

It is recalled that steam exit-fraction will play a significant role in the determination of the final optimum design. The baseline exit-fraction of 13 percent predicted by CONDIP for the DDG-37 condenser is unsatisfactory. Therefore a more reasonable upper limit of 1 percent was placed on this constraint. Although CONDIP will return a much more conservative design if 1 percent vice 13 percent is used as the upper limit, the subsequent design will be much more credible.

Finally, the amount of tube sheet material that can be removed by drilling for the installation of condenser tubes is specified at 24 percent of the total tube sheet area in [Ref. 17]. This area ratio limit represents a structural limit imposed to ensure that the tube sheets do not fail due to heat and pressure stresses in the condenser. However, CONDIP does not take into account the space between the condenser and tube shell normally used in area ratio calculations as blank tube sheet area. For this reason and to allow more flexibility in the design analysis, the constraint limit was set at 30 percent.

In summary, the general design constraints and the associated upper and lower bounds were:

$$0.625 \leq \text{tube outer diameter (inch)} \leq 1.25$$

$$1.0 \leq \text{bundle diameter (feet)} \leq 10.0$$

$$\text{steam exit-fraction (\%)} \leq 1.0$$

$$\text{VLCMAX (ft/sec)} \leq 200.0$$

$$\text{area ratio} \leq .30$$

These design constraints and associated bounds were used in all the case studies except where specifically modified.

2. Design Variable Framework for CONDIP

At least eight design variables were used in all the case studies. They include tube inner diameter, tube wall thickness, tube pitch, the number of tubes in the condenser, tube length, the inner void radius, the percent of the tubes in the cooler, and cooling water velocity. Side constraints were placed on all of these variables to correspond to either realistic physical limits or available standardized materials.

Tube wall thickness was not allowed to fall below 0.022 inches (BWG 24) or exceed .109 inches (12 BWG), sizes normally available commercially. Tube inner diameter was restricted to values between .407 and 1.206 inches so as to yield tube outer diameters within the limits specified earlier.

Tube pitch is defined as the ratio of the center to center spacing between adjacent tubes in a row to the tube outer diameter. Tube pitch is an accurate measure of how closely packed the tube bundle is. Generally accepted values for pitch lie in the range of 1.3 to 1.7. However, to provide more latitude in the design process this design variable was allowed to vary in the range between 1.1 to 2.0.

There is no guidance available as to the allowable range for tube length in the condenser. Since the lower limit was not expected to be crucial, it was set randomly at 1.0 feet. The upper limit of 25.0 feet was a realistic limit considering the size of the tube diameter being worked with. Inner void radius and the percent of tubes in the cooler were chosen to be design variables simply to enhance the

flexibility of the code in designing the condenser model. The bounds for both variables were entirely arbitrary with only common sense as the determining factor. The upper and lower limits on the percent of tubes in the cooler was established as 10.0 and 2.0 percent respectively. The upper and lower bounds on the inner void radius was set at 1.0 and 0.1 feet.

Cooling water velocity generally ranges from three to nine feet per second in value for all common tube materials, except titanium which has an upper limit of 15 feet per second. Exceeding these upper limits risks excessive tube erosion and material damage. Finally the number of tubes was permitted to vary between 1000 and 8000 tubes for the purpose of improving design flexibilty. It is extremely unlikely that, for most propulsion applications, tube number would fall below 1000. The upper limit was simply chosen as a realistic cutoff point in terms of complexity, cost and maintainability.

In summary, the general design variables and the associated side-constraints were:

$$0.407 \leq \text{tube inner diameter (inches)} \leq 1.206$$
$$0.022 \leq \text{tube thickness (inches)} \leq 0.109$$
$$2.0 \leq \text{percent of tubes in cooler} \leq 10.0$$
$$0.10 \leq \text{inner void radius (feet)} \leq 1.0$$
$$3.0 \leq \text{coolant velocity (ft/sec)} \leq 9.0$$
$$1.0 \leq \text{tube length (feet)} \leq 25.0$$
$$1000 \leq \text{tube number} \leq 8000$$
$$1.1 \leq \text{tube pitch} \leq 2.0$$

As in the case of design constraints, these design variables and their respective limits were used consistently in all the case studies unless otherwise specified.

C. CASE STUDIES USING CONDIP

1. Case One

The objective of this case was to minimize condenser volume. The final results of the optimization along with the initial parameters is listed in Table III.

These results show a 16 percent decrease in condenser volume with a corresponding 24 percent increase in pumping power. The source of the improvement can be understood by noting the following:

1) Tube wall thickness was reduced from 0.049 to 0.022, the minimum side-constraint, thus allowing tube inner diameter to increase while maintaining a minimum tube outer diameter.

2) The number of tubes shrank slightly as did tube length, resulting in a smaller heat transfer surface area.

3) Tube pitch increased markedly, causing a reduction in steam pressure losses which then ensured that high values for steam saturation pressure and temperature would be maintained throughout the condenser. The large pitch also reduced steam velocities, allowing the cooler inlet velocity limit to be satisfied. Row spacing decreased from the initial value of 1.35 inches, thus decreasing condenser volume.

4) Cooling water velocity increased to the maximum allowable value of 9 ft/sec which correspondingly resulted in larger head losses and coolant flow, causing overall pumping power to increase.

As cooling water velocity increased and tube wall thickness decreased, then their respective thermal resistances were diminished. The cumulative effect was to improve the overall heat transfer coefficient. LMTD rose primarily as a result of the higher steam temperatures throughout the condenser. It is apparent by looking at equation 5.2 that increasing the driving forces for heat

transfer, such as the overall heat transfer coefficient and LMTD, allows the heat transfer surface area to decrease. This resulted in a similar reduction in condenser volume.

The constraint limits that prevented further design improvement were the upper bound on the cooling water velocity, the upper limit on the tube sheet area and the upper limit on VLCMAX.

2. Case Two

The objective of this case was to minimize the pumping power required to overcome the tube-side head losses and drive the cooling water through the condenser tubes. The final results of the optimization are presented along with the initial design in Table IV.

The results indicate a dramatic 90 percent reduction in required pumping power with an equally large 120 percent increase in condenser volume. The major factors involved in the design improvement along with their relative effects are briefly explained below:

1) Tube inner diameter increased 27 percent while tube thickness remained relatively unchanged. Thus tube outer diameter was caused to increase.

2) The number of tubes in the condenser rose significantly, along with tube length. This, coupled with the enlarged tube outer diameter resulted in nearly doubling the heat transfer area.

3) Tube pitch icreased 29 percent, which allowed steam saturation pressure and temperature to be maintained at consistently large values in the condenser. This had a benefiting effect on the associated LMTD calculation. The large pitch also helped satisfy the steam velocity limit into the cooler. The tube spacing decreased from the initial value of 1.35, but by a smaller amount than the previous case because of the large values for tube pitch and outer diameter.

4) Cooling water velocity dropped to the minimum allowable limit of 3 ft/sec. This had the effect of reducing tube-side head losses and coolant flow through the condenser. Consequently, pumping power was drastically reduced.

The combined effect of all these changes can again be put in perspective by looking at equation 5.2. For the given steam and corresponding heat load, the heat transfer area increased drastically, allowing both LMTD and the overall heat transfer coefficient to decrease. A smaller overall heat transfer implies a smaller convective tube-side contribution which in turn permits coolant velocity to reduce to its lowest allowable value. The LMTD decrease is explained by the fact that cooling water was spending more time in the tubes, thus causing the average cooling water temperature to rise. However, the subsequent reduction in LMTD was minimized by the fact that a high steam temperature was maintained in the condenser.

There were no active constraints in this design outside of cooling water velocity which prevented further design improvement. However, the penalty paid in terms of a huge condenser volume, appears prohibitive.

3. Case Three

The objective of this case was to minimize pumping power while holding condenser volume constant at the initial value of 432 cubic feet. This was a particularly interesting test case as the results in Table V bear out. The required pumping power was reduced by nearly 38 percent with no change in volume. The effects of the design changes which resulted in the design improvement are presented below:

1) Tube inner diameter increased noticeably. However, the effects of this increase on tube outer diameter was minimized by a large drop in tube wall thickness. Thus, tube outer diameter remained relatively unchanged.

2) The number of tubes experienced a minor reduction, while tube length increased. The overall effect was to increase heat transfer surface area.

3) Tube pitch again rose by nearly 25 percent, causing steam saturation temperature and pressure to maintain a nearly constant value throughout the condenser. This had a beneficial effect on the LMTD between the steam and the cooling water. The larger pitch also had the additional effect of reducing steam velocity thus allowing the subsequent design to satisfy the upper limit on steam velocity into the cooler (VLCMAX). The combination of tube pitch and tube outer diameter resulted in a reduction in row spacing from the initial value of 1.35

4) Cooling water velocity decreased by about 21 percent. This effect was manifested in subsequent pressure head, coolant flow and pumping power calculations.

Looking at equation 5.2 we see the same general pattern emerging as in Case 3, but with more subtlety in the changes. Heat transfer increased, but not at the expense of volume. Cooling water velocity was allowed to decrease while the overall heat transfer coefficient actually rose. One explanation is that as the tube wall got thinner its thermal resistance got smaller which more than offset the loss of convective heat transfer contribution from the coolant. The LMTD dropped slightly due to the higher average coolant temperature of the coolant in the tubes.

The constraints which became active and prevented further improvement in the design include tube sheet area ratio as well as tube wall thickness. However, tube wall thickness was particular crucial because of its related effect on heat transfer.

4. Case Four

The objective of this case was to minimize condenser volume while holding pumping power constant at the initial value of 55.7 horsepower. The results of this case can be found in Table VI. Chosen to contrast the results in Case 4, the relative improvement in this design objective was not nearly so impressive. Condenser volume shrank by only 12 percent. An explanation of the causes and effects is provided below:

1) Tube inner diameter increased, with a corresponding decrease in tube wall thickness to yield the minimum allowable tube outer diameter.

2) The number of tubes decreased noticeably, tending minimize bundle volume. Note, there was only slight increase in tube length. The overall effect was to similarly reduce heat transfer surface area as condenser volume decreased.

3) Tube pitch again increased significantly, having the same effects on steam pressure, temperature and steam velocity into the cooler as discussed earlier. A large tube pitch benefits the LMTD between the steam and the cooling water. Row spacing was again a factor in reducing condenser volume as before.

4) Cooling velocity decreased slightly as did head loss. But overall coolant flow increased due to an increase in tube inner diameter. The net effect was to maintain pumping power.

Again, referring to equation 5.2 , it is clear that the slight decrease in heat transfer area was offset by the slight rise in LMTD resulting from higher condenser steam temperatures. The significant improvement in overall heat transfer coefficient, therefore, is what makes the heat balance work. The large decrease in tube wall thickness and corresponding reduction in thermal resistance contributed heavily to this improvement.

There were several contraint limits which prevented any additional objective optimization. They include the minimum tube wall thickness, tube sheet area ratio and steam velocity entering the cooler.

5. Case Five

The objective of this case was to minimize condenser volume while exercising CONDIP's capabilities to linearly vary tube pitch and tube inner diameter by row. Thirty-five rows were used, which was the identical number as the initial design. Tube pitch and tube inner diameter of both the outermost and innermost rows served as design variables in this case. However - because tube number is now a dependent variable based on the number of rows, tube pitch, and tube diameter - it could not be used as a design variable. The optimized results of this analysis along with the initial design are presented in Table VII.

The results of this test case indicate a condenser volume which is 20 percent smaller than the initial design as compared to a 16 percent decrease in Case 1. The basic reasons and explanations as to why volume was able to be reduced remain fundamentally the same as in Case 1. Attention will therefore be focussed on the effects of linearly varying pitch and tube diameter. Final tube pitch ranged in value from 1.75 in the inner row to 1.44 in the outer row. Similarly, tube inner diameter ranged from .729 in the inner row to .583 in the outer row.

It is believed that smaller pitch and inner diameter were used in the outer row because of the higher available steam saturation pressure and temperature. The resulting higher steam velocities enhanced the beneficial effects of vapor shear on the external heat transfer coefficient thereby improving heat transfer on the outer rows. As steam pressure decreased, then tube pitch and tube inner diameter

increased to compensate and extract all the available heat from the steam. Consequently, steam velocity decreased and was able to satisfy to the limit imposed on the cooler entrance velocity. The end result is a condenser geometry that makes complete use of the available resources and conforms to the geometry to take advantage of the thermal conditions in the condenser. The big limitation with this approach is that the number of rows is held constant. Thus the subsequent condenser is designed around that value and the subsequent optimum design is a function of the number of rows specified.

TABLE I

Input Design Data

PARAMETER	VALUE
Total number of tubes	5230
Tube length (feet)	10.3
Tube inner diameter (inches)	0.527
Tube wall thickness (inches)	0.049
Tube outer diameter (inches)	0.625
Tube mat'l thermal conductivity btu/(ft-hr-^{o}F)	26.0
Tube pitch	1.38
Percent of tubes in the cooler	7.0
Steam inlet flow (lbm/hr)	161,961
Fraction of non-condensible gas (ppm)	37.1
Steam inlet pressure (psia)	1.294
Steam inlet temperature (^{o}F)	110.52
Coolant inlet velocity (ft/sec)	8.473
Coolant inlet temperature (^{o}F)	75.66
Fouling factor	.0002
Inner void diameter (feet)	1.1
Row spacing (inches)	1.35

TABLE II

CONDIP Verification Results

PARAMETER	EXPERIMENT RESULTS	CONDIP RESULTS	CHANGE (%)
Heat transfer area (sq.ft.)	8805	8814	+0.10
Overall heat transfer coefficient btu/(hr-sq.ft.-^{o}F)	635.2	547.9	-9.5
Log mean temperature difference (^{o}F)	28.24	28.62	+1.3
Coolant temperature rise (^{o}F)	10.61	9.90	-6.7
Coolant mass flow rate (10^{7} lbm/hr)	1.503	1.540	+2.5
Condenser volume (cu.ft.)	-----	432.3	-----
Bundle diameter (ft)	5.7 7.2	7.17	-----
Shell-side pressure drop (psia)	0.751	1.29	+71.8
Steam exit-fraction (% of input)	-----	13.3	-----
Heat rejected (10^{8} btu/hr)	1.595	1.451	-9.03
Area ratio	0.291	0.266	-8.59

TABLE III

Volume Minimization

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	5117	-2.2
% of tubes in cocler	7.0	7.01	+0.1
Tube length (ft)	10.3	9.92	-3.7
Tube inner diam. (in)	.527	.582	+10.4
Tube wall thick. (in)	.049	.022	-55.1
Tube outer diam. (in)	.625	.626	+0.2
Tube pitch	1.4	1.73	+23.6
Void diameter (ft)	1.10	1.34	+21.8
Bundle diameter (ft)	7.17	6.59	-8.1
Condenser volume (cu.ft.)	432.3	362.2	-16.2
Area ratio	0.266	0.300	+12.7
Coolant inlet vel. (ft./sec)	8.473	9.00	+6.2
Coolant mass flow rate (10^7 lbm/hr)	1.540	1.955	+26.9
Head loss (ft H2O)	7.35	7.18	-2.3
Pumping power (hp)	55.69	68.99	+23.9
Coolant temperature rise (^{0}F)	9.90	9.00	-9.1
Log mean temperature difference (^{0}F)	28.62	29.13	+1.8
Heat transfer area (sq.ft.)	8814.	8320.	-5.6
Average overall heat transfer coefficient btu/(hr-sq.ft.-^{0}F)	574.9	689.9	+20.0
Steam exit-fraction (% of input)	13.3	0.0	-100.
Heat rejected (10^6 btu/hr)	1.451	1.672	+15.2

TABLE IV

Power Minimization

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	6393	+22.2
% of tubes in cocler	7.0	7.4	+5.7
Tube length (ft)	10.3	13.34	+29.5
Tube inner diam. (in)	.527	.667	+26.6
Tube wall thick. (in)	.049	.0455	-7.1
Tube outer diam. (in)	.625	.758	+21.3
Tube pitch	1.4	1.812	+29.4
Void diameter (ft)	1.10	1.13	+2.7
Bundle diameter (ft)	7.17	9.25	+29.0
Condenser volume (cu.ft.)	432.3	964.4	+123.1
Area ratio	0.266	0.277	+4.1
Coolant inlet vel. (ft./sec)	8.473	3.00	-64.6
Coolant mass flow rate (10^7 lbm/hr)	1.540	1.067	-30.7
Head loss (ft H2O)	7.35	1.11	-84.9
Pumping power (hp)	55.69	5.84	-89.5
Coolant temperature rise (^{0}F)	9.90	16.3	+64.6
Log mean temperature difference (^{0}F)	28.62	24.82	-13.3
Heat transfer area (sq.ft.)	8814.	16,921	+92.0
Average overall heat transfer coefficient btu/(hr-sq.ft.-^{0}F)	574.9	393.8	-31.5
Steam exit-fraction (% of input)	13.3	1.0	-92.5
Heat rejected (10^8 btu/hr)	1.451	1.654	+14.0

TABLE V

Power Minimization With Volume Constant

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	5062	+3.2
% of tubes in cocler	7.0	6.7	-4.3
Tube length (ft)	10.3	11.39	+10.6
Tube inner diam. (in)	.527	.594	+12.7
Tube wall thick. (in)	.049	.022	-55.1
Tube outer diam. (in)	.625	.638	+2.1
Tube pitch	1.4	1.753	+25.2
Void diameter (ft)	1.10	1.14	+3.6
Bundle diameter (ft)	7.17	6.73	-6.1
Condenser volume (cu.ft.)	432.3	431.6	-0.2
Area ratio	0.266	0.297	+11.7
Coolant inlet vel. (ft./sec)	8.473	6.74	-20.5
Coolant mass flow rate (10^7 lbm/hr)	1.540	1.508	-2.1
Head loss (ft H2O)	7.35	4.69	-36.2
Pumping power (hp)	55.69	34.77	-37.6
Coolant temperature rise (^{0}F)	9.90	11.6	+17.2
Log mean temperature difference (^{0}F)	28.62	27.63	-3.5
Heat transfer area (sq.ft.)	8814.	9631.4	+9.3
Average overall heat transfer coefficient btu/(hr-sq.ft.-^{0}F)	574.9	627.3	+9.1
Steam exit-fraction (% of input)	13.3	0.0	-100.
Heat rejected (10^8 btu/hr)	1.451	1.669	+15.0

TABLE VI

Volume Minimization With Power Constant

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	4867	-6.9
% of tubes in cocler	7.0	7.2	+2.9
Tube length (ft)	10.3	10.92	+6.0
Tube inner diam. (in)	.527	.581	+10.2
Tube wall thick. (in)	.049	.022	-55.1
Tube outer diam. (in)	.625	.625	0.0
Tube pitch	1.4	1.739	+24.2
Void diameter (ft)	1.10	1.20	+9.1
Bundle diameter (ft)	7.17	6.41	-10.6
Condenser volume (cu.ft.)	432.3	378.4	-12.4
Area ratio	0.266	0.299	+12.4
Coolant inlet vel. (ft./sec)	8.473	8.27	-2.4
Coolant mass flow rate (10^7 lbm/hr)	1.540	1.701	+10.5
Head loss (ft H2O)	7.35	6.67	-9.3
Pumping power (hp)	55.69	55.80	+0.2
Coolant temperature rise (^{0}F)	9.90	10.34	+4.4
Log mean temperature difference (^{0}F)	28.62	28.38	-0.8
Heat transfer area (sq.ft.)	8814.	8697.	-1.3
Average overall heat transfer coefficient btu/(hr-sq.ft.-^{0}F)	574.9	677.4	+17.5
Steam exit-fraction (% of input)	13.3	0.0	-100.
Heat rejected (10^8 btu/hr)	1.451	1.672	+15.2

TABLE VII

Volume Minimization With Linear Variations

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	5348	+2.3
% of tubes in cocler	7.0	7.3	+4.3
Tube length (ft)	10.3	8.7	-15.5
Tube inner diam. (in)	.527	*.729 .583	----
Tube wall thick. (in)	.049	.022	-55.1
Tube outer diam. (in)	.625	*.773 .627	----
Tube pitch	1.4	*1.75 1.44	----
Void diameter (ft)	1.10	1.28	+16.4
Bundle diameter (ft)	7.17	6.8	-5.2
Condenser volume (cu.ft.)	432.3	345.8	-20.0
Area ratio	0.266	0.298	+12.0
Coolant inlet vel. (ft./sec)	8.473	9.0	+6.2
Coolant mass flow rate (10^7 lbm/hr)	1.540	2.48	+61.0
Head loss (ft H2O)	7.35	5.84	-20.5
Pumping power (hp)	55.69	71.1	+27.7
Coolant temperature rise (^{0}F)	9.90	7.1	-28.8
Log mean temperature difference (^{0}F)	28.62	30.14	+5.3
Heat transfer area (sq.ft.)	8814.	7746.	-12.1
Average overall heat transfer coefficient btu/(hr-sq.ft.-^{0}F)	574.9	713.1	+24.0
Steam exit-fraction (% of input)	13.3	0.5	-96.2
Heat rejected (10^8 btu/hr)	1.451	1.665	+14.7

* Inner row values followed by outer row values.

VI. CONCLUSIONS

The intent of this research was to create a detailed condenser analysis code capable of being coupled with a numerical optimizer and to test the program to prove its versatility. An additional objective was to validate the analysis with existing data. The results of the test cases were presented in Chapter Five; the resulting conlusions are summarized here.

A. There were significant difficulties encountered in formulating the complex condenser design anaysis, CONDIP, in a way that was compatible with the optimizer COPES/CONMIN. However, the majority of those problems were overcome resulting in the creation of a program which, when combined with the optimizer, is capable of taking any initial design, no matter how impractical or infeasible, and solving for an optimum solution based on a set of pre-determined constraints and design variables. There are still some minor limitations as to the degree of optimization, but the final design is usually within 10 pecent of the single best optimum. In addition, the test cases indicate that as many as ten design variables and six constraints can be used simultaneously in the design optimization with CONDIP.

B. The test cases demonstrated the effectiveness of CONDIP as a design tool for not only the conceptual design of a condenser, but also in evaluating comparison studies based on any number of design variable combinations. The number of possible combinations of design objectives, design variables and design constraints implies limitless possibilities to be explored and evaluated.

C. An attempt was made to verify CONDIP with existing data with inconclusive results. Part of the blame can be placed on the rather inadequate quality and quantity of the data, but the general performance of CONDIP's condenser indicates a weakness in the analysis. As stated earlier, the source of the this weakness may be found in the correlations used for condensate inundation. The constants used in the expression for correcting shell-side heat transfer coefficients are based somewhat on conjecture. Yet they play a significant role in the overall condenser performance. Despite this limitation, the ability to optimize CONDIP's detailed analysis is a significant step forward over using the traditional and limited HEI method.

D. CONDIP incorporates features that further increase its appeal as a design tool. By possessing the ability to linearly vary pitch and tube diameter, a better understanding of how to improve condenser performance based on its configuration is realized. The capability to incorporate shell-side tube enhancement is another added plus. The possibilities that can now be investigated are limitless.

VII. RECOMMENDATIONS

In addition to the insight that this investigation has given into the generation of automated condenser design programs, it has specifically addressed the shortcomings and pitfalls which may be encountered along the way and offered possible solutions to overcome them. Presented below are recommendations for furthering the developmentof CONDIP as a completely versatile and accepted design program.

A. Since the weak link and the most significant unknown in condenser analysis is the effect of condensate rain in typical condenser environments, subsequent research should be devoted to investigating this phenomenon and developing more precise analytic correlations. In particular, the effects of velocity and flow direction on the condensate film should be attended to.

B. Perhaps in conjunction with the above, a test condenser should be constructed which is geometrically similar to the model proposed in CONDIP in order to physically observe and record the condenser performance. This data could then be used to either verify CONDIP or strengthen some of its anaysis. In addition, this condenser should be built such that the tube bank can be arranged in any combination of pitch, tube diameter and row spacing to fully appreciate the effects of these variables.

C. A series of sensitivity studies should be conducted on CONDIP to fully exercise its capabilities and determine the relative effects of various designvariables on condenser performance. Tradeoff studies similar to those performed in this research would be most beneficial to fully understand condenser behavior.

D. Additicnal subroutines should be created which would allow tube enhancement to be a design variable. This involves developing correlations between heat transfer enhancement and associated frictional losses. This type of relationship can be developed for both tube-side and shell-side enhancement.

E. Finally, it is recommended that additional refinement be performed on the code to increase its capability and flexibility. One such way is to somehow allow pitch, tube diameter and tube wall thickness to vary linearly by row while still allowing the number of tubes to be a design variable. The options available are limitless.

APPENDIX A
GLOSSARY

While it would most beneficial to present a complete glossary of all the variables used in CONDIP, the sheer number makes it difficult to present a comprehensive list. However, CONDIP makes liberal use of comment cards to define as many variables as possible to make the code easier to follow. Therefore, the computer listing in Appendix C is available for reference. A list of the possible design variables and constraints is provided here along with its corresponding position in the **GLOBCM common block** for easy reference in writing the appropriate COPES data cards. In addition, it will be specified whether these variables can be used as design constraints or design variables.

1. ALST: The length of the condenser and cooler tubes in feet. ALST is to be used only as a design variable.

2. DELWP: The pressure difference between the inlet and outlet coolant headers of the condenser bundle in psi. DELWP is to be used only as a design variable.

3. DELWPC: The pressure difference between the inlet and outlet coolant headers of the condenser bundle in psi. DELWPC is to be used only as a design constraint.

4. GFLOW: The mass flow rate of the coolant in lbm/hour. GFLOW cannot be used as a design variable simultanouesly with VELBI. Otherwise it can be used as a design variable or a design constraint.

5. SIDI: The tube inner diameter of the innermost row of

the condenser bundle in inches. SIDI is to be used only as a design variable.

7. SIDO: The tube inner diameter of the outermost row of the condenser bundle in inches. If there is no linear variation of tube inner diameter then this variable represents the tube inner diameter of the entire condenser bundle. SIDO is to be used only as a design variable.

8. PHP: The coolant pumping power in horsepower. PHP is to be used only as a design constraint.

9. RSPA: The spacing between concentric rows in the condenser bundle in inches. RSPA is to be used only as a design variable.

10. RADINS: The inner void radius of the condenser bundle in feet. RADINS is to be used only as a design variable.

11. REWI: The tube-side Reynolds number of the coolant in the innermost row of the condenser bundle. REWI is to be used only as a design constraint.

12. REWO: The tube-side Reynolds number of the coolant in the outermost row of the condenser bundle. If there is no linear variation of tube inner diameter then this variable represents the tube-side Reynolds number of the entire condenser bundle. REWO is to be used only as a constraint.

13. SDDI: Tube pitch (tube spacing/tube outer diameter) of the innermost row of the condenser bundle. SDDI is to be used only as a a design variable.

14. SDDO: The tube pitch of the outermost row of the condenser bundle. If there is no linear variation of tube pitch then this variable represents the tube pitch for the entire condenser bundle. SDDO is to be used only as a design variable.

15. SLDI: Ratio of tube length to tube outer diameter of the outermost row of the condenser bundle. SLDI is to be used only as a design constraint.

16. SLDO: Ratio of tube length to tube outer diameter of the outermost row of the condenser bundle. If there is no linear variation of tube pitch then this variable represents the tube pitch for the entire condenser bundle. SLDO is to be used only as a design constraint.

17. VELBI: The velocity of the coolant in feet/sec. VELBI cannot be used as a design variable simultaneously with GFLOW. Otherwise it can be used as either a design constraint or as a design variable.

18. XW1: The ratio of tube thickness to tube inner diameter. XW1 can be used only as a design variable.

19. XW2: Tube thickness in inches. XW2 is to be used only as a design variable. XW2 and XW1 cannot be used simultaneously.

20. VOL1: The overall condenser and cooler volume in cubic feet. VOL1 is to be used only as a design constraint.

21. VOL2: The volume occupied by the tube bank, excluding the volume of the inner void, in cubic feet. VOL2 is to be used only as a design constraint.

22. TNOTOT: The total number of tubes in the condenser and cooler combined. If Option 1 is being used then TNOTOT is to be used only as a design constraint. If Option 2 is being used then TNOTOT is to be used only as a design variable.

23. BNDRAD: The condenser bundle in feet. BNDRAD is to be used only as a design constraint.

24. ARATIO: The ratio of the total cross-sectional area of

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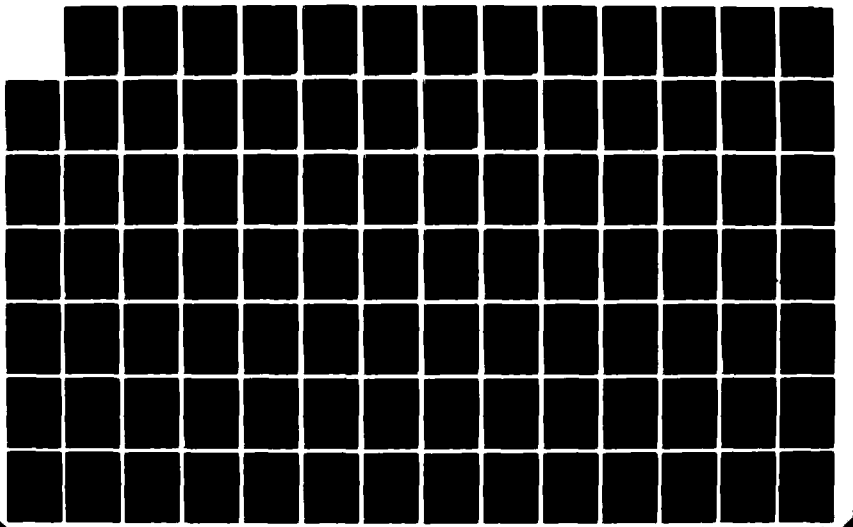

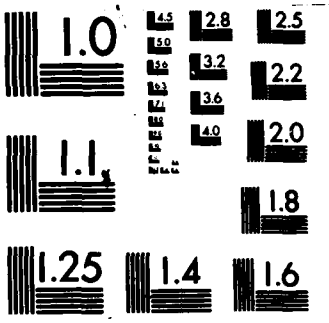

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the tubes (based on the tube outer diameter) to the tube sheet area. ARATIO is to be used only as a design constraint.

25. ODII: The tube outer diameter of the innermost row in inches. ODII is to be used only as a design constraint.

26. ODOI: The tube outer diameter of the outermost row in inches. If there is no linear variation of tube inner diameter then this variable represants the tube outer diameter of the entire condenser bundle. ODOI is to be used only as a design constraint.

27. VLCMAX: The maximum allowable steam velocity into the cooler. VLCMAX can be used only as a design constraint and only when a cooler is being designed in the system.

28. PRCCLR: The percent of the total number of tubes in the cooler. PRCCLR can be used only as a design variable.

APPENDIX B
USERS MANUAL FOR CONDIP

This appendix describes the data cards that are necessary in order to couple any design program with COPES/CONMIN. Also described are cards illustrating data input required by CONDIP to initiate analysis. Thus, the data is divided into the COPES/CONMIN program section and the CONDIP-based condenser design program section.

The COPES data is segmented into "blocks" for convenience. All formats are alphanumeric for title, end and stop cards; F10 for real data; and I10 for integer data. The formatted input may be overridden by inserting commas between data entries. Comment cards may be inserted anywhere in the data stack prior to the end card and are identified by a dollar sign ($) in column 1. The COPES data stack must terminate with an end card containing the word "END" in column 1-3. It should be noted that information pertaining only to single analysis and optimization is presented here. Information concerning the other options available in COPES along with further explanation of COPES capabilities can be found in [Ref. 13].

The analysis data is also segmented into blocks for convenience and they begin immediately following the "END" card in the COPES data. No comment cards are permitted here, and the analysis data stack must terminate with the word "STOP" in columns 1-4. This is where the initial design values are placed for entry into CONDIP.

Default values are recommended for use in the following COPES data cards unless otherwise noted. It is recommended that these values in the COPES data blocks be used until the user becomes familiar with the program. In addition a

sample data input is illustrated in figure B.1 at the end of this appendix.

DATA BLOCK A

DESCRIPTION: COPES Title Card

FORMAT: 20A4

1	2	3	4	5	6	7	8
TITLE							

REMARKS:

1) This line is available for a brief description.

DATA BLOCK B

DESCRIPTION: COPES Program Control Parameters

FORMAT: 7I10

1	2	3	4	5	6	7	8
NCALC	NDV						

FIELD		CONTENTS
1	NCALC:	Calculation control
	0	Read input and stop. Data of blocks A-B is required. Remaining data is optional.
	1	One cycle through the program. Data of blocks A-B is required. Remaining data is optional.
	2	Optimization. Data of blocks A-I is required. Remaining data is optional.
2	NDV:	Number of independent design variables in optimization or optimum sensitivity study.

REMARKS:

1) Field 1 determines program execution

2) Fields 3-8 are to be left blank for the CONDIP application of COPES/CONMIN.

DATA BLOCK C

DESCRIPTION: COPES Integer Optimization Control Parameters

FORMAT: 8I10

1	2	3	4	5	6	7	8
IPRINT	ITMAX	ICNDIR	NSCAL	ITRM	LINOBJ	NACMX1	NFDG

FIELD		CONTENTS
1	IPRINT:	Print control used in optimization program, CONMIN.
	0	No print during optimization.
	1	Print initial and final optimization information.
	2	Print above plus function value and design variable values at each iteration.
	3	Print above plus constraint values, direction vector and move parameter at each iteration.
	4	Print above plus gradient information.
	5	Print above plus each proposed design vector, objective function and constraints during the one-dimensional search. required. Remaining data is optional.
2	ITMAX:	Maximum number of optimization iterations allowed. DEFAULT = 20.
3	ICNDIR:	Conjugate direction restart parameter. DEFAULT = NDV+1.
4	NSCAL:	Scaling parameter. GT.0 - Scale design variables to order of magnitude one every NSCAL iterations. LT.0 - Scale design variables according to scaling values input. DEFAULT = No scaling.
5	ITRM:	Number of subsequent iterations which must satisfy relative or absolute convergence criterion before optimization process is terminated. DEFAULT = 3.
6	LINOBJ:	Linear objective function identifier. If the optimization objective is known to be a linear function of the design variables, set LINOBJ = 1. DEFAULT = Non-Linear.
7	NACMX1:	one plus the maximum number of active constraints anticipated. DEFAULT = NDV+2.

DATA BLOCK C (Continued)

FIELD		CONTENTS
8	NFDG:	Finite difference gradient identifier.
	0	All gradient information is computed by finite difference.
	1	Gradient of objective is computed anaytically. Gradients of constraints are computed by finite difference.
	2	All gradient information is computed analytically

REMARKS:

1) The value of NSCAL = 0 is suggested and ITRM = NACMX1 = 0 should be used.

2) The value of IPRINT may be reduced when the user becomes familiar with the optimization output.

3) The default values will be used if the card is either left blank or a value of zero is entered.

4) Because of the complexity of the problem it is necessary to have a large value for ITMAX so the problem will not be terminated prematurely. Recommended value is ITMAX = 40

5) The complexity of the condenser analysis ensure that no function can be considered linearly dependent on any combination of variables. This justifies using the DEFAULT value for LINOBJ.

DATA BLOCK D

DESCRIPTION: COPES Floating Point Optimization Program Parameters

FORMAT: 8F10

1	2	3	4	5	6	7	8
FDCH	FDCHM	CT	CTMIN	CTL	CTLMIN	THETA	PHI

FIELD		CONTENTS
1	FDCH:	Relative change in design variables in calculating finite difference gradients. DEFAULT = 0.01
2	FDCHM:	Minimum absolute step in finite difference gradient calculations. DEFAULT = 0.001.
3	CT:	Constraint thicknass parameter. DEFAULT = -0.1.
4	CTMI:	Minimum absolute value of CT considered in the optimization process. DEFAULT = 0.004
5	CTL:	Constraint thicknass parameter for linear and side constraints.
6	CTLMIN:	Minimum absolute value of CTL considered in the optimization process. DEFAULT = 0.001
7	THETA:	Mean value of push-off factor in the method of feasible directions. DEFAULT = 1.0
8	PHI:	Participation coefficient, used if one or more constraints are violated. DEFAULT = 5.0.

DATA BLOCK D (continued)

FORMAT: 2F10

1	2	3	4	5	6	7	8
DELFUN	DABFUN						

FIELD		CONTENTS
1	DELFUN:	Minimum relative change in objective function to indicate convergence of optimization process. DEFAULT = 0.001.
2	DABFUN:	Minimum absolute change in objective function to indicate convergence of the optimization process. DEFAULT = 0.001 times the initial objective value.

REMARKS:

1) Note that data for Data Block D is entered on two separate cards. A blank card indicates the default value is to be used.

2) If the NDV is greater than 3, the recommended value for FDCH is between 0.05 and 0.10.

DATA BLOCK E

DESCRIPTION: Total Number of Design Variables, Design Objective Identification and Sign on Design Objective.

FORMAT: 2I10, F10

1	2	3	4	5	6	7	8
NDVTOT	IOBJ	SGNOPT					

FIELD		CONTENTS
1	NDVTOT:	Total number of variables linked to the design variables. NDVTOT must be greater or equal to NDV. This option allows two or more parameters to be assigned to a single design variable. The value of each parameter is the value of the design variable times a multiplier which may be different for each parameter. DEFAULT = NDV.
2	IOBJ:	Global variable number associated with objective function in optimization or optimum sensitivity analysis.
3	SGNOPT:	Sign used on objective of optimization to identify whether function is to be maximized or minimized. +1.0 indicates maximization; -1.0 indicates minimization. DEFAULT = -1.0

REMARKS:

1) Currently there are not any variables in CONDIP which are linked to any of the design variables. Therefore the DEFAULT value is used for NDVTOT.

DATA BLOCK F

DESCRIPTION: Design Variable Bounds, Initial Values, and Scaling Factors.

FORMAT: 4F10

1	2	3	4	5	6	7	8
VLB	VUB	X	SCAL				

FIELD		CONTENTS
1	VLB:	Lower bound on the design variable.
2	VUB:	Upper bound on the design variable.
3	X:	Initial value of the design variable. If X is non-zero, this will supercede the value initialized by subroutine ANALIZ.
4	SCAL:	Design variable scale factor. Not used if NSCAL ≥ 0 in Block C

REMARKS:

1) There must be one separate data card for each design variable. Therefore there will be NDV data cards.

2) For all applications with CONDIP, initial values for the design variables will be entered through the INPUT subroutine called in ANALIZ.

DATA BLOCK G

DESCRIPTION: Design Variable Identification

FORMAT: 2I10,F10

1	2	3	4	5	6	7	8
NDSGN	IDSGN	AMULT					

FIELD		CONTENTS
1	NDSGN:	Design variable number associated with the variable.
2	IDSGN:	Global variable number associated with the variable.
3	AMULT:	Constant multiplier on the variable. The value of the variable will be the value of the design variable, NDSGN, times AMULT. DEFAULT = 1.0.

REMARKS:

1) There must be one separate card for each of the NDVTOT design variables. These data cards must follow the same order as the corresponding design variable parameter cards in Block F.

DATA BLOCK H

DESCRIPTION: Number of Constrained Parameters.

FORMAT: I10

1	2	3	4	5	6	7	8
NCONS							

FIELD		CONTENTS
1	NCONS:	Number of constraint SETS in the optimization problem.

REMARKS:

1) If two or more adjacent parameters in the Global common block have the same limits imposed, these are part of the same constraint set.

DATA BLOCK I

DESCRIPTION: Constraint Identification and Bounds.

FORMAT: 3I10

1	2	3	4	5	6	7	8
ICON	JCON	LCON					

FIELD	CONTENTS	
1	ICON:	First Global number corresponding to the constraint set.
2	JCON:	Last Global number corresponding to the constraint set. DEFAULT = ICON.
3	LCON:	Linear constraint identifier for this set of constrained variables. LCON = 1 indicates linear constraints. DEFAULT = 0 = Nonlinear constraint.

REMARKS:

1) In CONDIP there is only Global number and thus one constraint that comprise a constraint set. Therefore the DEFAULT value is used for JCON.

2) All the constraints in this analysis are nonlinear. The DEFAULT value was therefore used for LCON as well.

3) This is the first card of a two card set which must be read together.

DATA BLOCK I (Continued)

FORMAT: 4F10

1	2	3	4	5	6	7	8
BL	SCAL1	BU	SCAL2				

FIELD		CONTENTS
1	BL:	Lower bound on the constrained variables. Value less than -2.0E+15 is assumed unbounded
2	SCAL1:	Normalization factor on lower bound. DEFAULT = Max of ABS(BL) or 0.1.
3	BU:	Upper bound on the constrained variables. Value greater than +2.0E+15 is assumed unbounded.
4	SCAL2	Normalization factor on upper bound. DEFAULT = Max of ABS(BU) or 0.1.

REMARKS:

1) The normalization factor can usually be defaulted, with the notable exception of exit-fraction. the normalization factor used for this constraint is usually ten times the upper bound.

DATA BLOCK P

DESCRIPTION: COPES Data 'END' Card.

FORMAT: 3A1

1	2	3	4	5	6	7	8
END							

FIELD	CONTENTS
1	The word 'END' in column 1-3.

REMARKS:

1) This card must appear at the end of the COPES data.
2) This ends the COPES input deck.

DATA BLOCK AA

DESCRIPTION: Geometry Option

FORMAT: I5

1	2	3	4	5	6	7	8
IOPT							

FIELD		CONTENTS
1	IOPT	Two condenser geometric options
	1	IOPT = 1. Number of condenser rows is a input as a constant; the number of tubes is a dependant variable. Use data blocks EE, FF, and GG.
	2	IOPT = 2. Number of tubes is allowed to be an independant variable and the number of rows is a dependent variable. Use data blocks HH and II. DEFAULT value is IOPT = 2.

REMARKS:

1) Data is right-justified and blanks will be interpreted as zeros.

2) If IOPT = 1, a smaller finite difference (FDCH) can be utilized in data Block D. This is because with this option the design analysis is less sensitive to the problems discussed earlier. Recommended using the DEFAULT value of 0.01 for FDCH.

DATA BLOCK BB

DESCRIPTION: Condenser Orientation

FORMAT: 1I5,3F10

1	2	3	4	5	6	7	8
ISEC	SECWID	PHI	PRCCLR				

FIELD		CONTENTS
1	ISEC	The number of sectors in the condenser.
2	SECWID	Sector width in degrees of arc.
3	PHI	Symmetry angle measure from the vertical.
4	PRCCLR	The percent of the tubes in the cooler.

REMARKS:

1) Data BB is required, no matter what geometry option is chosen.

2) The only limitation on ISEC and SECWID is that their product is less than 360 degrees. If the product is exactly 360 degrees, certain trigonometric functions will return a singularity.

3) PHI is that angle from the vertical that cuts the condenser in half.

4) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK CC

DESCRIPTION: Void Size, Tube Length, Row Spacing

FORMAT: 3F10

1	2	3	4	5	6	7	8
RADINS	ALST	RSPA					

FIELD		CONTENTS
1	RADINS	The inner void radius; feet.
2	ALST	The tube length; feet.
3	RSPA	Concentric row spacing about the void; inches.

REMARKS:

1) Data CC is required, no matter what geometry option is chosen.

DATA BLOCK DD

DESCRIPTION: Tube Material Parameters

FORMAT: I5,4F10

1	2	3	4	5	6	7	8
IWALL	XW	TUBESW	SKW	FOUL			

FIELD		CONTENTS
1	IWALL	A Flag indicating the tube thickness specification.
	1	IWALL = 1. Tube thickness is input as ratio of tube thickness to tube inner diameter.
	2	IWALL = 2. Tube thickness is input in inches.
2	XW	The input for wall thickness, dependent on the value for IWALL.
3	TUBESW	Specifc weight of the tube material; lbm/(cu.ft.)
4	SKW	Tube material thermal conductivity; (btu-ft)/(sq.ft.-hr-°F)
5	FOUL	Tube fouling factor.

REMARKS:

1) Data DD is required, no matter what geometry option is chosen.

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK EE

DESCRIPTION: Number of Rows

FORMAT: I5

1	2	3	4	5	6	7	8
NOROWS							

FIELD		CONTENTS
1	NOROWS	The number of concentric rows in the condenser bundle built around the center void

REMARKS:

1) Data EE is used only when IOPT = 1

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK FF

DESCRIPTION: Tube Inner Diameter

FORMAT: 1I5,2F10

1	2	3	4	5	6	7	8
MDIAM	SIDO	SIDI					

FIELD		CONTENTS
1	MDIAM	A flag to indicate whether tube inner diameter will linearly vary by row through the condenser bunile.
	1	MDIAM = 1. Tube inner diameter is uniform through the condenser bundle.
	2	MDIAM = 2. Tube inner diameter varies linearly through the bundle by row.
2	SIDO	Tube inner diameter of the outer row; inches.
3	SIDI	Tube inner diameter of the inner row; inches.

REMARKS:

1) Data FF is used only when IOPT = 1

2) Data is right-justified and blanks will be interpreted as zeros.

3) Ccoler tubes use the inner diameter of the innermost bundle row.

4) The DEFAULT value is MDIAM = 1

DATA BLOCK GG

DESCRIPTION: Tube Pitch

FORMAT: 1I5,2F10

1	2	3	4	5	6	7	8
MPITCH	SDDO	SDDI					

FIELD		CONTENTS
1	MPITCH	A flag to indicate whether tube pitch will linearly vary by row through the condenser bundle.
	1	MPITCH = 1. Tube pitch is uniform through the condenser bundle.
	2	MPITCH = 2. Tube pitch varies linearly through the bundle by row.
2	SDDO	Tube pitch of the outer row;
3	SDDI	Tube pitch of the inner row;

REMARKS:

1) Data GG is used only when IOPT = 1

2) Data is right-justified and blanks will be interpreted as zeros.

3) Cooler tubes use the pitch of the innermost bundle row.

4) The DEFAULT value is MPITCH = 1

DATA BLOCK HH

DESCRIPTION: Tube Inner Diameter and Tube Pitch

FORMAT: 2F10

1	2	3	4	5	6	7	8
SIDO	SDDO						

FIELD		CONTENTS
1	SIDO	Tube inner diameter for the entire condenser; inches
2	SDDO	Tube pitch for the entire condenser

REMARKS:

1) Data HH is used only when IOPT = 2.

2) Data is right-justified and blanks will be interpreted as zeros.

3) In the calculations, SIDI is set equal to SIDO and SDDI is set equal to SDDO. This avoids the need for two systems of nomenclature for each geometry option.

DATA BLOCK II

DESCRIPTION: Total Number of Tubes in the Condenser

FORMAT: F12

1	2	3	4	5	6	7	8
TNOTOT							

FIELD		CONTENTS
1	TNOTOT	The total number of tubes in the condenser (cooler and the bundle).

REMARKS:

1) Data II is used only when IOPT = 2.

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK JJ

DESCRIPTION: Inlet Steam Mixture.

FORMAT: 15,2F10

1	2	3	4	5	6	7	8
JGAS	WSI	WNCIR					

FIELD		CONTENTS
1	JGAS	A Flag indicating the type of non-condensable gas entering the system.
	1	JGAS = 1. This indicates that the gas is air.
	2	JGAS = 2. This indicates that the gas is carbon dioxide.
	3	JGAS = 3. This indicates that the gas is a mixture of the two.
2	WSI	Steam flow rate entering the condenser; lbm/hr.
3	WNCIR	Ratio of the non-condensable gas flow to inlet steam flow; lbm/hr.

REMARKS:

1) Data JJ is required, no matter what geometry option is chosen.

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK KK

DESCRIPTION: Inlet Temperatures.

FORMAT: 2F10

1	2	3	4	5	6	7	8
STBI	STSAT1						

FIELD		CONTENTS
1	STBI	Coclant inlet temperature; °F.
2	STSAT1	Inlet steam saturation temperature; °F.

REMARKS:

1) Data KK is required no matter, what geometry option is chosen.

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK LL

DESCRIPTION: Cooling Water Parameters

FORMAT: 2F10

1	2	3	4	5	6	7	8
IFLOW	X5						

FIELD		CONTENTS
1	IFLOW	A control flag for cooling water specifications.
	1	IFLOW = 1. Input pressure drop across cooling water heaters in psia.
	2	IFLOW = 2. Input cooling water velocity in ft/sec.
	3	IFLOW = 3. Input coolant flow in lbm/hr.
2	X5	Actually input the value for flow into this variable. The specification for flow to be determined by IFLOW

REMARKS:

1) Data LL is required, no matter what geometry option is chosen.

2) Data is right-justified and blanks will be interpreted as zeros.

3) X5 acts as a temporary all-purpose storage variable for whatever expression for coolant flow is used.

DATA BLOCK MM

DESCRIPTION: Internal Enhancement Regions

FORMAT: I5

1	2	3	4	5	6	7	8
NEI							

FIELD		CONTENTS
1	NEI	Number of internal enhancement regions. A value between 1 and 6.

REMARKS:

1) Data MM is optional. There must be NEI subsequent data cards providing the necessary paramaters for each region.

2) enhancement can only be used if IOPT = 1.

3) Data is right-justified and blanks will be interpreted as zeros.

4) This value was zero for all runs.

DATA BLOCK NN

DESCRIPTION: Internal Enhancement Parameters

FORMAT: 2I5,3F10

1	2	3	4	5	6	7	8
NRNI	NETI	ENI	BC	BE			

FIELD		CONTENTS
1	NRNI	Row number of first row in internal enhancement region.
2	NETI	Number of tubes in each internal enhancement region.
3	ENI	Internal heat transfer enhancement factor.
4	BC	Coefficient in internallyenhanced tube coolant pressure drop calculation.
5	BE	Exponent in coolant pressure drop calculation.

REMARKS:

1) Data NN is optional. However, if NEI is greater than zero then there must NEI "NN" data cards to provide the necessary data for each enhancement region.

2) enhancement can only be used if IOPT = 1.

3) Data is right-justified and blanks will be interpreted as zeros.

4) These values are constant for entire run and cannot be changed by the optimizer.

5) This value was zero for all runs.

DATA BLOCK 00

DESCRIPTION: External Enhancement Regions

FORMAT: I5

1	2	3	4	5	6	7	8
NEE							

FIELD		CONTENTS
1	NEE	Number of external enhancement regions. A value between 1 and 6.

REMARKS:

1) Data 00 is optional. There must be NEE subsequent data cards providing the necessary parameters for each region.

3) Data is right-justified and blanks will be interpreted as zeros.

4) This value was zero for all runs.

DATA BLOCK PP

DESCRIPTION: External Enhancement Parameters

FORMAT: 2I5,2F10

1	2	3	4	5	6	7	8
NRNE	NETE	ENO	ENH				

FIELD		CONTENTS
1	NRNE	Row number of first row in external enhancement region.
2	NETE	Number of tubes in each external enhancement region.
3	ENI	External heat transfer enhancement factor.
4	ENH	Steam-side pressure drop factors.

REMARKS:

1) Data PP is optional. However, if NEE is greater than zero then there must NEE "PP" data cards to provide the necessary data for each enhancement region.

2) Data is right-justified and blanks will be interpreted as zeros.

3) Enhancement can only be used if IOPT = 1.

4) These values are constant for an entire run and cannot be changed by the optimizer.

5) This value was zero for all runs.

DATA BLOCK QQ

DESCRIPTION: Baffle Options

FORMAT: I5

1	2	3	4	5	6	7	8
IBAF							

FIELD		CONTENTS
1	IBAF	A flag to be used to determine baffle number and location.

REMARKS:

1) Data QQ is optional.

2) Data is right-justified and blanks will be interpreted as zeros.

3) These values are constant for an entire run and cannot be changed by the optimizer.

4) Additional specified baffles were not used in any of the runs. This value was zero for all runs.

DATA BLOCK RR

DESCRIPTION: Baffle Location

FORMAT: I5

1	2	3	4	5	6	7	8
JBAF							

FIELD		CONTENTS
1	JBAF	An array containing baffle locations

REMARKS:

1) Data RR is optional.

2) Data is right-justified and blanks will be interpreted as zeros.

3) These values are constant for an entire run and cannot be changed by the optimizer.

4) Additional specified baffles were not used in any of the runs. This value was zero for all runs.

DATA BLOCK SS

DESCRIPTION: Detailed Printout

FORMAT: I5

1	2	3	4	5	6	7	8
IPRT							

FIELD		CONTENTS
1	IPRT	A flag to generate a detailed output of the condenser analysis (OUT3)

REMARKS:

1) Data SS is optional.

2) Data is right-justified and blanks will be interpreted as zeros.

3) These values are constant for an entire run and cannot be changed by the optimizer.

4) This value was zero for all runs.

```
VOLUME MINIMIZATION - CIRCULAR CONDENSOR
2,8
1,40,,9,,,20
.10

1,20,-1.
1.0,2.0E+15
1000.,8000.
1.1,2.
3.,9.0
.022,.109
.407,1.206
.1,1.
2.,10.
1,1
2,22
3,14
4,17
5,19
6,7
7,10
8,29
5
4
-2.0E+15,,.01,.01
23
.5,,5.
24
.1,,.30
26
.625,,1.25
28
-2.E+15,,200.
END
    2
   12  29.99   180.          7.0
  0.55          10.3
    2    .049       282.        26.0     .0002
   .527          1.40
   5230.0
    1   161970.   .0000371
  76.66    110.52
    2    8.473
    0
    0
    0
    0
```

Figure B.1 Sample Data Input.

APPENDIX C
CONDIP LISTING

The following Appendix contains a complete listing for CONDIP. An effort has been made to make the program as readable as possible through liberal use of comment cards.

```
      SUBROUTINE ANALIZ (ICALC)                                          CON00010
C     IF (ICALC.GT.2) RETURN                                             CON00020
      IF (ICALC.GT.1) GO TO 10                                           CON00030
      ICOUNT=0                                                           CON00040
      CALL INPUT (IPRT)                                                  CON00050
      CALL OUT1                                                          CON00060
10    IF (ICALC.EQ.3) GO TO 20                                           CON00070
      CALL ORCON (ICALC)                                                 CON00080
      GO TO 30                                                           CON00090
20    CALL OUT2                                                          CON00100
C     ICOUNT = 1                                                         CON00110
      IF (IPRT.NE.0.AND.ICOUNT.NE.0) CALL OUT3                           CON00120
      ICOUNT=ICOUNT+1                                                    CON00130
30    RETURN                                                             CON00140
      END                                                                CON00150
C                                                                        CON00160
C*************************************************************************CON00170
C*************************************************************************CON00180
C                                                                        CON00190
      SUBROUTINE INPUT (IPRT)                                            CON00200
C--------------                                                          CON00210
C INP 1                                                                  CON00220
C                     SUBROUTINE INPUT                                   CON00230
C                                                                        CON00240
C                INPUT CALLED BY ANALIZ WITH ICALC = 1                   CON00250
C                                                                        CON00260
C ZZZ INP-1                                                              CON00270
C--------------                                                          CON00280
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITQA,GFLOW,SIDI,SIDO,PHP,RSPA,CON00290
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNUTUCON00300
     2T,BNDRAD,ARATIO,ODII,ODDI,SDDC,VLCMAX,PRCCLR                       CON00310
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FDUL,PHI,SKW,STBI,SCON00320
     1TSATI,TUBESW,NCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON00330
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NORDWS,WTST(15)CON00340
     3,WSI,PFILL                                                         CON00350
      COMMON /INPT1/ IFLOW,IWALL                                         CON00360
C$--------------                                                         CON00370
C INP 2                                                                  CON00380
C                     READ ENTERING DATA SET                             CON00390
C                                                                        CON00400
C        ALST = TUBE LENGTH IN FEET                                      CON00410
C        BC = COEFICIENT IN INTERNALLY ENHANCED TUBE COOLANT PRESSURE    CON00420
C             DROP CALCULATION.                                          CON00430
C        BE = EXPONENT IN COOLANT PRESSURE DROP CALCULATION.             CON00440
C        DELWP = PRESSURE DROP ACROSS COOLANT WATER HEADERS,  PSI        CON00450
C        ENI = INTERNAL HEAT TRANSFER ENHANCEMENT FACTORS.               CON00460
C        ENH = STM SIDE PRESSURE DROP FACTORS.                           CON00470
C        ENO = EXTERNAL HEAT TRANSFER ENHANCEMENT FACTORS.               CON00480
```

```
C          FOUL = TUBE FOULING FACTOR.                                          CON00490
C          GFLOW = COOLANT MASS FLOW RATE  LBM/HR                               CON00500
C          IBAF = CONTROL FLAG FOR BAFFLE OPTIONS                               CON00510
C          IFLOW = CONTROL FLAG FOR COOLING WATER SPECIFICATION.                CON00520
C          IPRT = CONTROL FLAG FOR OUTPUT.  (EXTENDED OUTPUT IF IPRT>0.)        CON00530
C          ISEC = NO. OF SECTORS IN CONDENSER                                   CON00540
C          IWALL = CONTROL FLAG FOR TUBE THICKNESS SPECIFICATION.               CON00550
C          JBAF = ARRAY CONTAINING BAFFLE LOCCATIONS.                           CON00560
C          JGAS = N/C GAS IDENTIFIER 1,2, OR 3                                  CON00570
C          MDIAM = CONTROL FLAG FOR LINEAR VARIATION IN TUBE DIAMETER.          CON00580
C          MPITCH = CONTROL FLAG FOR LINEAR VARIATION IN TUBE PITCH.            CON00590
C          NEE = NUMBER OF EXTERNAL ENHANCEMENT REGIONS.                        CON00600
C          NEI = NUMBER OF INTERNAL ENHANCEMENT REGIONS.                        CON00610
C          NETE = NUMBER OF TUBES IN EACH EXTERNAL ENHANCEMENT REGION.          CON00620
C          NETI = NUMBER OF TUBES IN EACH INTERNAL ENHANCEMENT REGION.          CON00630
C          NOROWS = NUMBER OF ROWS IN THE CONDENSER                             CON00640
C          NRNE = ROW NUMBER OF FIRST ROW IN EXTERNAL ENHANCEMENT REGION.       CON00650
C          NRNI = ROW NUMBER OF FIRST ROW IN INTERNAL ENHANCEMENT REGION.       CON00660
C          SIDI = TUBE ID AT INSIDE ROW - IN                                    CON00670
C          SIDO = TUBE ID AT OUTSIDE ROW - IN                                   CON00680
C          IOPT = FLAG TO INDICATE WHICH GEOMETRY MODULE IS BEING USED          CON00690
C                 IF OPT=1 THEN NOROWS IS A CONSTANT IN THE MODEL AND           CON00700
C                 VARIATION IN PITCH AND TUBE DIAMETER IS PERMITTED.            CON00710
C                 IF OPT=2 THEN TNOTOT IS A DESIGN VARIABLE AND LINEAR          CON00720
C                 VARIATIONS ARE NOT PERMITTED.                                 CON00730
C          PHI    = SYMETRY ANGLE MEASURED FROM THE VERTICAL                    CON00740
C          RADINS = BUNDLE INSIDE RADIUS - FT                                   CON00750
C          RSPA = TUBE ROW RADIAL SEPARTATION - IN                              CON00760
C          SDDI = PITCH AT INSIDE ROW                                           CON00770
C          SDDO = PITCH AT OUTSIDE ROW                                          CON00780
C          SECWID = SECTOR WIDTH IN DEGREES OF ARC                              CON00790
C          SKW = TUBE MATERIAL THERMAL CONDUCTIVITY  BTU-FT/HR-FT**2-F          CON00800
C          STBI = COOLANT INLET TEMP   F                                        CON00810
C          STSATI = INLET STM SAT TEMP   F                                      CON00820
C          TNOTOT = TOTAL NUMBER OF TUBES IN THE CONDENSOR/COOLER               CON00830
C          TUBESW = SPECIFIC WEIGHT OF THE TUBE MATERIAL  LBM/CU FT             CON00840
C          VELBI = COOLANT FLOW VELOCITY  FT/SEC                                CON00850
C          WNCIR = RATIO OF N/C MASS FLOW TO STEAM MASS FLOW                    CON00860
C          WSI = STM FLOW RATE  LBM/HR                                          CON00870
C          XW = TEMP INPUT VALUE OF XW1 AND XW2                                 CON00880
C          XW1 = RATIO OF TUBE WALL THICKNESS TO TUBE ID                        CON00890
C          XW2 = TUBE WALL THICKNESS  INCHES                                    CON00900
C                                                                               CON00910
C  ZZZ INP-2                                                                    CON00920
C--------------                                                                 CON00930
      READ (5,330) IOPT                                                         CON00940
      READ (5,340) ISEC,SECWID,PHI,PRCCLR                                       CON00950
      READ (5,360) RADINS,ALST,RSPA                                             CON00960
```

```
      READ (5,400) IWALL,XW,TUBESW,SKW,FOUL                              CON00970
C                                                                        CON00580
      IF ((IOPT.GE.2).OR.(IOPT.LT.1)) GO TO 10                           CON00990
C                                                                        CON01000
      READ (5,380) NOROWS                                                CON01010
      READ (5,370) MDIAM,SIDO,SIDI                                       CON01020
      READ (5,370) MPITCH,SDDO,SDDI                                      CON01030
      GO TO 20                                                           CON01040
10    READ (5,360) SIDO,SDDO                                             CON01050
      READ (5,390) TNOTOT                                                CON01060
      MPITCH=1                                                           CON01070
      MDIAM=1                                                            CON01080
C                                                                        CON01090
20    IF (MDIAM.EQ.1) SIDI=SIDO                                          CON01100
      IF (MPITCH.EQ.1) SDDI=SDDO                                         CON01110
      IW=IWALL                                                           CON01120
      IF (IWALL.NE.2) IW=1                                               CON01130
      XW1=0.                                                             CON01140
      XW2=0.                                                             CON01150
      IF (IW.EQ.1) XW1=XW                                                CON01160
      IF (IW.EQ.2) XW2=XW                                                CON01170
      READ (5,350) JGAS,WSI,WNCIR                                        CON01180
      READ (5,410) STBI,STSAT1                                           CON01190
      READ (5,420) IFLOW,X5                                              CON01200
      IFL=IFLOW                                                          CON01210
      GFLOW=0.                                                           CON01220
      VELBI=0.                                                           CON01230
      DELWP=0.                                                           CON01240
      IF (IFLOW.EQ.1) DELWP=X5                                           CON01250
      IF (IFLOW.EQ.2) VELBI=X5                                           CON01260
      IF (IFLOW.EQ.3) GFLOW=X5                                           CON01270
      READ (5,430) NEI                                                   CON01280
      IF (NEI.EQ.0) GO TO 40                                             CON01290
      IF ((NEI.LT.0).AND.(NEI.GT.6)) GO TO 120                           CON01300
      DO 30 I=1,NEI                                                      CON01310
30    READ (5,440) NRNI(I),NETI(I),ENI(I),BC(I),BE(I)                    CON01320
40    READ (5,430) NEE                                                   CON01330
      IF (NEE.EQ.0) GO TO 60                                             CON01340
      IF ((NEE.LE.0).OR.(NEE.GT.6)) GO TO 120                            CON01350
      DO 50 I=1,NEE                                                      CON01360
50    READ (5,450) NRNE(I),NETE(I),ENO(I),ENH(I)                         CON01370
60    READ (5,430) IBAF                                                  CON01380
      IF ((IBAF.LE.-2).OR.(IBAF.GT.ISEC)) GO TO 120                      CON01390
      IF ((IBAF.EQ.0).OR.(IBAF.EQ.-1)) GO TO 80                          CON01400
      DO 70 I=1,IBAF                                                     CON01410
70    READ (5,430) JBAF(I)                                               CON01420
80    CONTINUE                                                           CON01430
      READ (5,430) IPRT                                                  CON01440
```

```
C$-------------
C INP 3
C                    TEST FOR RECOVERABLE INPUT ERRORS
C
C ZZZ INP-3
C-------------
      IF ((IOPT.EQ.1).OR.(IOPT.EQ.2)) GO TO 90
      WRITE (6,460)
      WRITE (6,470) IOPT
      WRITE (6,510)
      IOPT=2
90    IF (IOPT.EQ.2) GO TO 110
      IF ((MDIAM.EQ.2).OR.(MDIAM.EQ.1)) GO TO 100
      WRITE (6,460)
      WRITE (6,480) MDIAM
      WRITE (6,510)
      MDIAM=1
100   IF ((MPITCH.EQ.1).OR.(MPITCH.EQ.2)) GO TO 110
      WRITE (6,460)
      WRITE (6,490) MPITCH
      WRITE (6,510)
      MPITCH=1
110   IF ((IWALL.EQ.1).OR.(IWALL.EQ.2)) GO TO 120
      WRITE (6,460)
      WRITE (6,500) IWALL
      WRITE (6,510)
      IWALL=1
C$-------------
C INP 4
C                    LOCATE NON-RECOVERABLE INPUT ERRORS
C
C ZZZ INP-4
C-------------
120   IERR=0
      IF ((ISEC.GT.0).AND.(ISEC.LE.15)) GO TO 130
      IERR=1
      WRITE (6,520)
      WRITE (6,530) ISEC
130   X2=SECWID*FLOAT(ISEC)
      IF ((X2.LE.360.).AND.(X2.GT.0.)) GO TO 140
      WRITE (6,520)
      WRITE (6,540) X2
      WRITE (6,550) ISEC,SECWID
      IERR=1
140   IF (IOPT.EQ.2) GO TO 150
      IF ((NOROWS.GT.0).AND.(NOROWS.LE.99)) GO TO 160
      IERR=1
      WRITE (6,520)
```

```
      WRITE (6,560) NCROWS                                              CON01930
      GO TO 160                                                         CON01940
C                                                                       CON01950
150   IF (TNOTOT.GT.0) GO TO 160                                        CON01960
      IERR=1                                                            CON01970
      WRITE (6,520)                                                     CON01980
      WRITE (6,570) TNOTOT                                              CON01990
C                                                                       CON02000
160   IF (RADINS.GT.0.) GO TO 170                                       CON02010
      IERR=1                                                            CON02020
      WRITE (6,520)                                                     CON02030
      WRITE (6,580) RADINS                                              CON02040
170   IF (ALST.GT.0.) GO TO 180                                         CON02050
      IERR=1                                                            CON02060
      WRITE (6,520)                                                     CON02070
      WRITE (6,590) ALST                                                CON02080
180   IF (SIDO.GT.0.) GO TO 190                                         CON02090
      IERR=1                                                            CON02100
      WRITE (6,520)                                                     CON02110
      WRITE (6,600) SIDO                                                CON02120
190   IF ((MDIAM.EQ.1).OR.(SIDI.GT.0.)) GO TO 200                       CON02130
      IERR=1                                                            CON02140
      WRITE (6,520)                                                     CON02150
      WRITE (6,610) SIDI                                                CON02160
200   IF (SDDO.GT.1.) GO TO 210                                         CON02170
      IERR=1                                                            CON02180
      WRITE (6,520)                                                     CON02190
      WRITE (6,620) SDDO                                                CON02200
210   IF ((MPITCH.EQ.1).OR.(SDDI.GT.1.)) GO TO 220                      CON02210
      IERR=1                                                            CON02220
      WRITE (6,520)                                                     CON02230
      WRITE (6,630) SDDI                                                CON02240
220   IF (IW.EQ.2) GO TO 230                                            CON02250
      IF (XW1.GT.0.) GO TO 240                                          CON02260
      IERR=1                                                            CON02270
      WRITE (6,520)                                                     CON02280
      WRITE (6,640) XW1                                                 CON02290
      GO TO 240                                                         CON02300
230   X=XW2*2.                                                          CON02310
      IF (X.GT.0.) GO TO 240                                            CON02320
      IERR=1                                                            CON02330
      WRITE (6,520)                                                     CON02340
      WRITE (6,650) XW2                                                 CON02350
240   IF ((WNCIR.GE.0.).AND.(WNCIR.LT.1.)) GO TO 250                    CON02360
      IERR=1                                                            CON02370
      WRITE (6,520)                                                     CON02380
      WRITE (6,660) WNCIR                                               CON02390
250   IF ((STBI.GT.-32.).AND.(STBI.LT.212)) GO TO 260                   CON02400
```

```
      IERR=1                                                                CON02410
      WRITE (6,520)                                                         CON02420
      WRITE (6,670) STBI                                                    CON02430
  260 IF (STBI.LT.STSAT1) GO TO 270                                         CON02440
      IERR=1                                                                CON02450
      WRITE (6,520)                                                         CON02460
      WRITE (6,680) STBI,STSAT1                                             CON02470
  270 IF ((IFLOW.GT.0).OR.(IFLOW.LE.3)) GO TO 280                           CON02480
      IERR=1                                                                CON02490
      WRITE (6,520)                                                         CON02500
      WRITE (6,690) IFLOW                                                   CON02510
  280 IF ((NEI.GE.0).AND.(NEI.LE.6)) GO TO 290                              CON02520
      IERR=1                                                                CON02530
      WRITE (6,520)                                                         CON02540
      WRITE (6,700) NEI                                                     CON02550
  290 IF ((NEE.GE.0).AND.(NEE.LE.6)) GO TO 300                              CON02560
      IERR=1                                                                CON02570
      WRITE (6,520)                                                         CON02580
      WRITE (6,710) NEE                                                     CON02590
  300 IF ((IBAF.GE.-1).AND.(IBAF.LE.ISEC)) GO TO 310                        CON02600
      IERR=1                                                                CON02610
      WRITE (6,520)                                                         CON02620
      WRITE (6,720) IBAF,ISEC                                               CON02630
      WRITE (6,730)                                                         CON02640
  310 IF (IERR.EQ.0) GO TO 320                                              CON02650
      STOP                                                                  CON02660
  320 RETURN                                                                CON02670
  330 FORMAT (I5)                                                           CON02680
  340 FORMAT (I5,3F10.5)                                                    CON02690
  350 FORMAT (I5,F10.5,F10.7)                                               CON02700
  360 FORMAT (4F10.5)                                                       CON02710
  370 FORMAT (I5,F10.5,F10.5)                                               CON02720
  380 FORMAT (I5)                                                           CON02730
  390 FORMAT (F12.5)                                                        CON02740
  400 FORMAT (I5,4F10.5)                                                    CON02750
  410 FORMAT (2F10.5)                                                       CON02760
  420 FORMAT (I5,F10.5)                                                     CON02770
  430 FORMAT (I5)                                                           CON02780
  440 FORMAT (2I5,3F10.5)                                                   CON02790
  450 FORMAT (2I5,2F10.5)                                                   CON02800
  460 FORMAT (1H0,31H***  WARNING - INPUT ERROR  ***)                       CON02810
  470 FORMAT (1H ,22H INPUT VALUE OF OPT = ,I5,27H OUT OF RANGE, OPT SETCON02820
     1 TO 2)                                                                CON02830
  480 FORMAT (1H ,21HINPUT VALUE OF MDIAM=,I5,29H OUT OF RANGE, MDIAM SECON02840
     1T TO 1)                                                               CON02850
  490 FORMAT (1H ,22HINPUT VALUE OF MPITCH=,I5,30H OUT OF RANGE, MPITCH CON02860
     1SET TO 1)                                                             CON02870
  500 FORMAT (1H ,21HINPUT VALUE OF IWALL=,I5,29H OUT OF RANGE, IWALL SECON02880
```

```
     1T TO 1)
510   FORMAT (1H ,26H   EXECUTION CONTINUES ...)
520   FORMAT (1H0,38H****  RUN TERMINATED DURING INPUT ****)
530   FORMAT (1H ,43HRANGE OF ALLOWABLE ISEC IS 1 THRU 15, ISEC=,I5)
540   FORMAT (1H ,60HCONDENSER ANGULAR WIDTH IS OUT OF RANGE 0 TO 360 DE
     1G, WIDTH=,E10.5,5H DEG.)
550   FORMAT (1H ,5HISEC=,I5,10H   SECWID=,E10.3)
560   FORMAT (1H ,49HNUMBER OF ROWS MUST BE IN RANGE 0 TO 100, NOROWS=,I
     15)
570   FORMAT (1H ,51HTHE NUMBER OF TUBES MUST BE GREATER THAN 0, TNOTOT=
     1,F12.5)
580   FORMAT (1H ,48HBUNDLE RADIUS MUST BE GREATER THAN ZERO, RADINS=,E1
     10.3)
590   FORMAT (1H ,44HTUBE LENGTH MUST BE GREATER THAN ZERO, ALST=,E10.3)
600   FORMAT (1H ,50HTUBE INNER DIAMETER MUST BE GREATER THAN 0, SIDO =,
     1E10.3)
610   FORMAT (1H ,50HTUBE INNER DIAMETER MUST BE GREATER THAN 0, SIDO =,
     1E10.3)
620   FORMAT (1H ,40HTUBE PITCH MUST BE GREATER THAN 1, SDDO=,E10.3)
630   FORMAT (1H ,40HTUBE PITCH MUST BE GREATER THAN 1, SDDI=,E10.3)
640   FORMAT (1H ,75HRATIO OF TUBE THICKNESS TO TUBE INNER DIAMETER MUST
     1 BE GREATER THAN 0, XW1=,E10.3)
650   FORMAT (1H ,49HTUBE THICKNESS MUST BE GREATER THAN 0, XW2=,E10.3)
660   FORMAT (1H ,93HRATIO OF N/C GASSES TO STM FLOW MUST BE LESS THAN O
     1NE  AND GREATER THAN EQUAL TO ZERO, WNCIR=,E10.3)
670   FORMAT (1H ,63HINJECTION TEMP MUST BE GREATER THAN 32 AND LESS THA
     1N 212, STBI=,E10.3)
680   FORMAT (1H ,58HINJECTION TEMP MUST BE LESS THAN EXHAUST TRUNK TEMP
     1, STBI=,E10.3,8H  STSAT=,E10.3)
690   FORMAT (1H ,31HIFLOW MUST BE 1,2 OR 3.  IFLOW=,I5)
700   FORMAT (1H ,73HNUMBER OF INTERNAL ENHANCEMENT REGIONS MUST BE BETW
     1EEN ZERO AND SIX, NEI=,I5)
710   FORMAT (1H ,73HNUMBER OF EXTERNAL ENHANCEMENT REGIONS MUST BE BETW
     1EEN ZERO AND SIX, NEE=,I5)
720   FORMAT (1H ,50HIBAF MUST BE BETWEEN -1 AND ISEC INCLUSIVE.  IBAF=,
     1I5,7H  ISEC=,I5)
730   FORMAT (1H ,40H(IF USER WANTS IBAF=ISEC+1, SET IBAF=-1))
      END
C
C*********************************************************************
C*********************************************************************
C
      SUBROUTINE OUT1
C---------------
C OUT1 1
C                  OUTPUT OF ENTERING DATA SET
C ZZZ OUT1-1
C              SEE INP-2 FOR VARIABLE DEFINITIONS
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C-------------                                                                  CON03370
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,CON03380
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNOTOCON03390
     2T,BNDRAD,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR                       CON03400
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON03410
     1TSAT1,TUBESW,NCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON03420
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON03430
     3,WSI,PFILL                                                        CON03440
      COMMON /INPT1/ IFLOW,IWALL                                        CON03450
      WRITE (6,60)                                                      CON03460
      WRITE (6,70)                                                      CON03470
      WRITE (6,80)                                                      CON03480
      WRITE (6,90)                                                      CON03490
      WRITE (6,100)                                                     CON03500
      WRITE (6,90)                                                      CON03510
      WRITE (6,80)                                                      CON03520
      WRITE (6,110)                                                     CON03530
      WRITE (6,120) ISEC                                                CON03540
      WRITE (6,130) SECWID                                              CON03550
      WRITE (6,140) PHI                                                 CON03560
      WRITE (6,150) PRCCLR                                              CON03570
      IF (IOPT.EQ.2) WRITE (6,170) TNOTOT                               CON03580
      IF (IOPT.EQ.2) GO TO 10                                           CON03590
      WRITE (6,160) NOROWS                                              CON03600
10    WRITE (6,180) RADINS                                              CON03610
      WRITE (6,190) ALST                                                CON03620
      WRITE (6,200) MDIAM                                               CON03630
      IF (MDIAM.EQ.0) GO TO 20                                          CON03640
      WRITE (6,210) SIDO                                                CON03650
      WRITE (6,240)                                                     CON03660
      GO TO 30                                                          CON03670
20    WRITE (6,220) SIDO,SIDI                                           CON03680
30    WRITE (6,230) MPITCH                                              CON03690
      IF (MPITCH.EQ.0) GO TO 40                                         CON03700
      WRITE (6,260) SDDO                                                CON03710
      WRITE (6,280)                                                     CON03720
      GO TO 50                                                          CON03730
40    WRITE (6,270) SDDO,SDDI                                           CON03740
50    WRITE (6,250) IWALL                                               CON03750
      IF (IWALL.EQ.1) WRITE (6,300) XW1                                 CON03760
      IF (IWALL.EQ.2) WRITE (6,290) XW2                                 CON03770
      WRITE (6,310) TUBESW                                              CON03780
      WRITE (6,320) SKW                                                 CON03790
      WRITE (6,330) FOUL                                                CON03800
      IF (JGAS.EQ.1) WRITE (6,360)                                      CON03810
      IF (JGAS.EQ.2) WRITE (6,370)                                      CON03820
      IF (JGAS.EQ.3) WRITE (6,380)                                      CON03830
      WRITE (6,340) WSI                                                 CON03840
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      WRITE (6,350) WNCIR                                                CON03850
      WRITE (6,390) STBI                                                 CON03860
      WRITE (6,400) STSAT1                                               CON03870
      WRITE (6,410) IFLOW                                                CON03880
      IF (IFLOW.EQ.3) WRITE (6,420) GFLOW                                CON03890
      IF (IFLOW.EQ.2) WRITE (6,430) VELBI                                CON03900
      IF (IFLOW.EQ.1) WRITE (6,440) DELWP                                CON03910
      WRITE (6,450) NEI                                                  CON03920
      WRITE (6,460) NEE                                                  CON03930
      WRITE (6,470) IBAF                                                 CON03940
      RETURN                                                             CON03950
60    FORMAT (1H1)                                                       CON03960
70    FORMAT (1H ,51H                GLOBAL COMMON BLOCK                 CON03970
     1/62H   1      2      3      4      5      6      7      8      9    CON03980
     2/62H ALST   DELWP DELWPC EXITOA  GFLOW  SIDI   SIDO   PHP   RSPA   CON03990
     3//62H    10     11     12     13     14     15     16     17     18 CON04000
     4 /61H  RADINS  REWI  REWO   SDDI   SDDO   SLDI   SLDO  VELBI  XW1   CON04010
     5//62H  19     20     21     22     23     24     25     26         CON04020
     6 /56H XW2   VOL1  VOL2  TNOTOT  BNDRAD   ARATIO   ODII   ODOI//)    CON04030
80    FORMAT (1H ,15X,16X,28H*****************************)             CON04040
90    FORMAT (1H ,15X,16X,1H*,26X,1H*)                                   CON04050
100   FORMAT (1H ,15X,16X,28H* CONDIP ENTERING DATA SET *)               CON04060
110   FORMAT (1H0///)                                                    CON04070
120   FORMAT (1H ,15X,17HNUMBER OF SECTORS,12X,I8)                       CON04080
130   FORMAT (1H ,15X,12HSECTOR WIDTH,18X,F9.1,10X,11HDEG. OF ARC)       CON04090
140   FORMAT (1H ,15X,24HBUNDLE ORIENTATION ANGLE,6X,F9.1,7X,14HDEG. FROCON04100
     1M VERT)                                                            CON04110
150   FORMAT (1H ,15X,53H% OF TOTAL TUBES ASSIGNED TO COOLER IS PRCCLR   CON04120
     1     = ,F5.2/)                                                     CON04130
160   FORMAT (1H ,15X,19HNUMBER OF TUBE ROWS,13X,I5)                     CON04140
170   FORMAT (1H ,15X,32HNUMBER OF TUBES IN THE CONDENSOR,8X,F12.5)      CON04150
180   FORMAT (1H ,15X,20HBUNDLE INSIDE RADIUS,12X,F10.4,16X,4HFEET)      CON04160
190   FORMAT (1H ,15X,11HTUBE LENGTH,19X,F10.2,5X,11X,4HFEET/)           CON04170
200   FORMAT (1H ,15X,37HFLAG FOR TUBE OD VARIATION IS MDIAM =,I2)       CON04180
210   FORMAT (1H ,15X,20HTUBE INSIDE DIAMETER,9X,F10.4,14X,6HINCHES)     CON04190
220   FORMAT (1H ,15X,20HTUBE INSIDE DIAMETER/15X,13X,11HOUTSIDE ROW,7X,CON04200
     1F10.2,14X,6HINCHES/15X,14X,10HINSIDE ROW,7X,F10.2,14X,6HINCHES/)   CON04210
230   FORMAT (1H ,15X,36HFLAG FOR PITCH VARIATION IS MPITCH =,I2)        CON04220
240   FORMAT (1H ,15X,39HTUBE DIAMETER IS A CONSTANT THRU BUNDLE/)       CON04230
250   FORMAT (1H ,15X,40HFLAG FOR TUBE WALL INPUT UNIT IS IWALL =,I2)    CON04240
260   FORMAT (1H ,15X,26HTUBE CIRCUMFERENTIAL PITCH,4X,F10.2)            CON04250
270   FORMAT (1H ,15X,26HTUBE CIRCUMFERENTIAL PITCH/15X,13X,11HOUTSIDE RCON04260
     1OW,7X,F11.3/15X,14X,10HINSIDE ROW,7X,F11.3/)                       CON04270
280   FORMAT (1H ,15X,29HPITCH IS CONSTANT THRU BUNDLE/)                 CON04280
290   FORMAT (1H ,15X,19HTUBE WALL THICKNESS,11X,F13.5,11X,6HINCHES)     CON04290
300   FORMAT (1H ,15X,31HWALL THICKNESS TO TUBE ID RATIO,F10.3)          CON04300
310   FORMAT (1H ,15X,25HTUBE WALL SPECIFIC WEIGHT,5X,F10.2,9X,8HLB/FT**CON04310
     13)                                                                 CON04320
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320   FORMAT (1H ,15X,25HTUBE THERMAL CONDUCTIVITY,5X,F10.2,9X,11HBTU/FTCON04330
     1-HR-F)                                                           CON04340
330   FORMAT (1H ,15X,19HTUBE FOULING FACTOR,11X,F13.5/)                CON04350
340   FORMAT (1H ,15X,20HSTEAM MASS FLOW RATE,9X,F9.0,16X,6HLBM/HR)     CON04360
350   FORMAT (1H ,15X,27HWEIGHT FRACTION OF N/C FLOW,3X,1PE13.5/)       CON04370
360   FORMAT (1H ,15X,14HN/C GAS IS AIR)                                CON04380
370   FORMAT (1H ,15X,25HN/C GAS IS CARBON DIOXIDE)                     CON04390
380   FORMAT (1H ,15X,46HN/C GAS IS A MISTURE OF AIR AND CARBON DIOXIDE)CON04400
390   FORMAT (1H ,15X,29HCOOLANT INJECTION TEMPERATURE,F10.1,16X,5HDEG FCON04410
     1)                                                                CON04420
400   FORMAT (1H ,15X,26HENTERING STEAM TEMPERATURE,4X,F9.2,16X,5HDEG F/CON04430
     1)                                                                CON04440
410   FORMAT (1H ,15X,28HCW FLOW SPECIFIER IS IFLCW =,I2)               CON04450
420   FORMAT (1H ,22X,22HCOOLANT MASS FLOW RATE,15X,F9.1,15X,6HLBM/HR/) CON04460
430   FORMAT (1H ,15X,16HCOOLANT VELOCITY,14X,F9.1,15X,6HFT/SEC/)       CON04470
440   FORMAT (1H ,15X,21HCOOLANT PRESSURE DROP,9X,F11.3,16X,3HPSI/)     CON04480
450   FORMAT (1H ,15X,38HNO. OF INTERNAL ENHANCEMENT REGIONS IS,I2)     CON04490
460   FORMAT (1H ,15X,38HNO. OF EXTERNAL ENHANCEMENT RETIONS IS,I2)     CON04500
470   FORMAT (1H ,15X,26HFLAG FOR BAFFLE IS IBAF = ,I5)                 CON04510
      END                                                               CON04520
C                                                                       CON04530
C***********************************************************************CON04540
C***********************************************************************CON04550
C                                                                       CON04560
      SUBROUTINE ORCON (ICALC)                                          CON04570
C-----------------                                                      CON04580
C ORC 1                                                                 CON04590
C                     SUBROUTINE ORCON                                  CON04600
C                                                                       CON04610
C               DIMENSION SIZE                                          CON04620
C                    X  = NO. OF ROWS + 1                               CON04630
C                    Y  = NO. OF SECTORS                                CON04640
C                    Z  = NO. OF ENHANCEMENT REGIONS                    CON04650
C                                                                       CON04660
C         TPAR(X)   AOTFLW(X)   RADIUS(X)   TBNPR(X)  VW(X)  SID(X)    CON04670
C         SECANG(Y)  WGAS(Y)  JBAF(Y+1)                                 CON04680
C         ANT(X,Y)    WS(X,Y)    VEL(X,Y)    PMIX(X,Y)                CON04690
C         BC(Z)  BE(Z)  ENI(Z)  ENO(Z)  NETI(Z)  NETE(Z)               CON04700
C         NRNE(Z)  NRNI(Z)                                              CON04710
C                                                                       CON04720
C ZZZ ORC-1                                                             CON04730
C-----------------                                                      CON04740
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,CON04750
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNUTUCON04760
     2T,BNDRAD,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCLR                       CON04770
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON04780
     1TSATI,TUBESW,WNCIR,IOPT,PIST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON04790
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON04800
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     3,WSI,PFILL                                                                CON04810
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMOUT(10CON04820
     10)                                                                        CON04830
      COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)                                  CON04840
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNO,VEL2,FR                      CON04850
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST                                 CON04860
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEFCON04870
     1F(100,15),PMIX(100,15),PSAT(100,15),QOA(100,15),RC(100,15),ROUT(10CON04880
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)CON04890
     3,VNRE(100,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WS(100,15CON04900
     4),WSP(15)                                                                 CON04910
      COMMON /OUT2A/ RCORR,RSPF,PHPCON,VCL1C                                    CON04920
C                                                                               CON04930
      DIMENSION TPAR(100),RADIUS(100),SECANG(15),BAFA(16)                       CON04940
C                                                                               CON04950
C$--------------                                                                CON04960
C ORC 2                                                                         CON04970
C                        DATA INITIALIZATION                                    CON04980
C                                                                               CON04990
C         AMWNC = MOLECULAR WEIGHT OF N/C GAS PRESENT                           CON05000
C         IFIRST IS A FLAG TO HETTRN TO INDICATE FIRST EXECUTION                CON05010
C         CBI = SALT CONCENTRATION OF COOLANT  WT. PRCNT                        CON05020
C         CPB = COOLANT SPECIFIC HEAT (UNITS?)                                  CON05030
C         PTST AND WTST ARE CONTRAINTS USED IN SEC-6                            CON05040
C                                                                               CON05050
C         VW(1) = IS INITIALIZED AS A SEED FOR AN ITERATIVE                     CON05060
C            CALCULATICN IN ORC-9                                               CON05070
C                                                                               CON05080
C ZZZ ORC-2                                                                     CON05090
C--------------                                                                 CON05100
      IF (ICALC.EQ.2) GO TO 20                                                  CON05110
      SG=32.174                                                                 CON05120
      PI=3.14159                                                                CON05130
      CBI=.035                                                                  CON05140
      CPB=1.                                                                    CON05150
      SECFLG=FLOAT(ISEC)                                                        CON05160
      WNCI=WSI*WNCIR                                                            CON05170
      A=1.                                                                      CON05180
      DO 10 I=1,ISEC                                                            CON05190
      WS(1,I)=WSI/SECFLG*A                                                      CON05200
10    WGAS(I)=WNCI/SECFLG*A                                                     CON05210
      IFIRST=1                                                                  CON05220
      IF (JGAS.EQ.1) AMWNC=28.965                                               CON05230
      IF (JGAS.EQ.2) AMWNC=44.                                                  CON05240
      IF (JGAS.EQ.3) AMWNC=36.5                                                 CON05250
      VW(1)=10.                                                                 CON05260
      GO TO 20                                                                  CON05270
C$--------------                                                                CON05280
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```
C ORC 3                                                                 CON05290
C                        ENTERING POINT FOR ICALC = 2                   CON05300
C                                                                       CON05310
C ZZZ ORC-3                                                             CON05320
C--------------                                                         CON05330
20     CONTINUE                                                         CON05340
       DO 30 I=1,ISEC                                                   CON05350
       WTST(I)=0.                                                       CON05360
30     PTST(I)=0.                                                       CON05370
C$-------------                                                         CON05380
C ORC 4                                                                 CON05390
C                              BUNDLE GEOMETRY                          CON05400
C                                                                       CON05410
C              TUBE PITCH IS DEFINED AS THE RATIO OF TUBE CENTER TO CENTECON05420
C              SPACING TO TUBE OD, MEASURED ALONG A ROW OF CONSTANT BUNDLCON05430
C              RADIUS.  ROW RADIAL SEPARATION IS NOT DIRECTLY RELATED TO CON05440
C              PITCH.                                                   CON05450
C                                                                       CON05460
C          AOTFLW = AREA OPEN TO STEAM FLOW IN EACH ROW I OF            CON05470
C                   A SECTOR                                            CON05480
C          AHOLES = AREA OF THE ENDS OF THE TUBES                       CON05490
C          ARATIO = TOTAL AREA OF THE ENDS OF THE TUBES DIVIDED BY THE  CON05500
C                   THE TUBE SHEET AREA THRU WHICH THE TUBES PASS       CON05510
C          ARCPR = CIRCUMFERENTIAL ARC LENGTH OF EACH SECTOR PER UNIT   CON05520
C                  RADIUS OF THE ROW BEING CONSIDERED                   CON05530
C          ALST = TUBE LENGTH   FT                                      CON05540
C          BNDRAD = TUBE BUNDLE RADIUS - FT                             CON05550
C          CSP = TUBE CNTR - CNTR SPACING AT A GIVEN ROW                CON05560
C          CSPI = CSP FOR INNER ROW                                     CON05570
C          CSPO = CSP FOR OUTER ROW                                     CON05580
C          DELCSP = RADIAL CHANGE IN CSP PER ROW  FT                    CON05590
C          DELODF = CHANGE IN TUBE OD / ROW  FT                         CON05600
C          FCWID = ANGULAR WIDTH OF CONDENSER MINUS ONE SECTOR   DEG    CON05610
C          ISEC = NUMBER OF SECTORS IN THE CONDENSER                    CON05620
C          NOROWS = NO. OF ROWS IN EACH SECTOR                          CON05630
C          OD = TUBE OD ON A GIVEN ROW  FT                              CON05640
C          ODOI = TUBE OD, OUTER ROW - IN                               CON05650
C          ODIF = TUBE OD, INNER ROW - FT                               CON05660
C          ODII = TUBE OD, INNER ROW - IN                               CON05670
C          ODOF = TUBE OD, OUTER ROW - FT                               CON05680
C          PRCCLR = PERCENT OF TOTAL TUBES ASSIGNED TO COOLER           CON05690
C          RAD = RADIUS OF A GIVEN ROW  FT                              CON05700
C          RADINS = BUNDLE INSIDE RADIUS - FT                           CON05710
C          RADIUS = RADIUS OF ROW I  FT                                 CON05720
C          RCORR = A CORRECTION FACTOR INTRODUCED TO SMOOTH THE STEP DIFFCON05730
C                  BETWEEN ROWS WHEN TUBES ARE ADDED OR DELETED         CON05740
C          ROWS = NO OF ROWS IN CONDENSER                               CON05750
C          RSPA = TUBE ROW RADIAL SEPARATION, IN                        CON05760
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C         RSPF = TUBE ROW RADIAL SEPARATION, FT                                  CON05770
C         SDDI = TUBE PITCH ON INSIDE ROW                                        CON05780
C         SDDO =  TUBE PITCH  ON  OUTSIDE ROW                                    CON05790
C         SECA = TEMP VALUE FOR SECANG   DEG                                     CON05800
C         SECANG = ANGLE FROM THE VERTICAL PASSING THROUGH EACH SECTOR           CON05810
C         SECFLG =  THE NUMBER OF SECTORS IN THE CONDENSER                       CON05820
C         SECWID = SECTOR WIDTH IN DEGREES OF ARC                                CON05830
C         SID = TUBE ID FOR EACH ROW   -  FT                                     CON05840
C         SIDIF = TUBE ID FOR INNER ROW IN FEET                                  CON05850
C         SIDI = TUBE ID FOR INNER ROW IN INCHES                                 CON05860
C         SIDOF = TUBE ID FOR OUTER ROW IN FEET                                  CON05870
C         SIDO = TUBE ID FOR OUTER ROW IN INCHES                                 CON05880
C         DELSDF = LINEAR VARIATION OF TUBE INNER DIAMETER                       CON05890
C         TBNPR = NO. OF TUBES IN ROW I OF EACH SECTOR                           CON05900
C         TNOTCT = TOTAL NO. OF TUBES IN CONDENSER + COOLER                      CON05910
C         TNO = NO. OF TUBES IN THE CONDENSER MODEL                              CON05920
C         TNOS = TOTAL NUMBER OF TUBES PER SECTOR                                CON05930
C         TNR = NUMBER OF TUBES IN A ROW OF A SECTOR                             CON05940
C         TPAR = TUBE DENSITY /UNIT AREA FOR EACH ROW  TUBES/FT**2               CON05950
C         TSAREA = TUBE SHEET AREA                                               CON05960
C         VOL1 = CONDENSOR VOLUME                                                CON05970
C         VOL1C = STORED CONDENSER VOLUME                                        CON05980
C         VOL2 = VOLUME ACTUALLY OCCUPIED BY THE CONDENSOR TUBE BUNDLE           CON05990
C         XW1 = RATIO OF TUBE WALL THICKNESS TO TUBE OD                          CON06000
C         XW2 = TUBE WALL THICKNESS  INCHES                                      CON06010
C                                                                                CON06020
C                   NOTE:  ADD CALC FOR SID                                      CON06030
C                                                                                CON06040
C              NOTE: RADIAL ROW SEPARATION IS CALCULATED                         CON06050
C                    AS THE AVERAGE OF CSPI AND CSPO UNLESS                      CON06060
C                    RSPA HAS A NON-ZERO VALUE FOR INPUT.                        CON06070
C                                                                                CON06080
C            VALUES CARRIED INTO THIS ROUTINE                                    CON06090
C         COMMON/NEW/ - , SECWID , NOROWS , RADINS , SDDO , SDDI ,               CON06100
C         COMMON/NEW/ - , ODII , ODOI , RSP , ISEC ,                             CON06110
C                                                                                CON06120
C  ZZZ ORC-4                                                                     CON06130
C---------------                                                                 CON06140
      IF (MDIAM.EQ.1) SIDI=SIDO                                                  CON06150
      IF (MPITCH.EQ.1) SDDI=SDDO                                                 CON06160
      ARCPR=6.283/360.*SECWID                                                    CON06170
      TNOS=0.0                                                                   CON06180
      SECFLG=FLOAT(ISEC)                                                         CON06190
C                                                                                CON06200
      IF (IOPT.EQ.2) GO TO 50                                                    CON06210
C                                                                                CON06220
CC    COMPUTATION OF GEOMETRY WHEN IOPT = 1                                      CON06230
C         NOROWS IS A CONSTANT                                                   CON06240
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C                                                                       CON06250
      AHOLES=0.                                                         CON06260
      ROWS=FLOAT(NOROWS)                                                CON06270
      SIDOF=SIDO/12.                                                    CON06280
      SIDIF=SIDI/12.                                                    CON06290
      DELSDF=(SIDOF-SIDIF)/(ROWS-1.)                                    CON06300
      IF (XW2.GT.0) ODOF=SIDOF+XW2/6.                                   CON06310
      IF (XW2.GT.0) ODIF=SIDIF+XW2/6.                                   CON06320
      IF (XW2.LE.0) ODOF=SIDOF+(2*SIDOF*XW1)                            CON06330
      IF (XW2.LE.0) ODIF=SIDIF+(2*SIDIF*XW1)                            CON06340
      ODOI=ODOF*12.                                                     CON06350
      ODII=ODIF*12.                                                     CON06360
      DELODF=(ODOF-ODIF)/(ROWS-1.)                                      CON06370
      DELOD=DELODF*12.                                                  CON06380
      CSPO=SDDO*ODOF                                                    CON06390
      CSPI=SDDI*ODIF                                                    CON06400
      DELCSP=(CSPO-CSPI)/(ROWS-1.)                                      CON06410
      RSPF=.866*(CSPO+CSPI)/2.                                          CON06420
      RSP=RSPF*12.                                                      CON06430
      IF (RSPA.NE.0.) RSP=RSPA                                          CON06440
      RSPF=RSP/12.                                                      CON06450
      BNDRAD=RADINS+RSPF*(ROWS-1.)                                      CON06460
      DO 40 I=1,NOROWS                                                  CON06470
      RAD=BNDRAD-RSPF*FLOAT(I-1)                                        CON06480
      CSP=CSPO-DELCSP*FLOAT(I-1)                                        CON06490
      TPAR(I)=1./(CSP*RSPF)                                             CON06500
      TNR=ARCPR*RAD/CSP                                                 CON06510
      OD=ODOF-DELODF*FLOAT(I-1)                                         CON06520
      SID(I)=SIDOF-DELSDF*FLOAT(I-1)                                    CON06530
      AOLFLW(I)=(CSP-OD)*TNR                                            CON06540
      AOTFLW(I)=AOLFLW(I)*ALST                                          CON06550
      TNOS=TNOS+TNR                                                     CON06560
      RADIUS(I)=RAD                                                     CON06570
      AHOLES=AHOLES+PI*(ODOF**2)*TNR/4.                                 CON06580
40    TBNPR(I)=TNR                                                      CON06590
      TNO=TNOS*SECFLG                                                   CON06600
      AHOLES=AHOLES*SECFLG                                              CON06610
      TNOTOT=TNO*100./(100.-PRCCLR)                                     CON06620
      GO TO 100                                                         CON06630
C                                                                       CON06640
CC                                                                      CON06650
50    CONTINUE                                                          CON06660
C                                                                       CON06670
C     COMPUTATION OF BUNDLE GEOMETRY IF IOPT = 2                        CON06680
CC       SIDI=SIDO                                                      CON06690
CC       SDDI=SDDO                                                      CON06700
C                                                                       CON06710
      ERR1=0.                                                           CON06720
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      TNOC=0.                                                          CONO6730
      TNOS=0.                                                          CONO6740
      TNR=0.                                                           CONO6750
      TDIFF=0.                                                         CONO6760
      SIDOF=SIDO/12.                                                   CONO6770
      SIDIF=SIDI/12.                                                   CONO6780
      IF  (XW2.GT.0)  ODOF=SIDOF+XW2/6.                                CONO6790
      IF  (XW2.GT.0)  ODIF=SIDIF+XW2/6.                                CONO6800
      IF  (XW2.LE.0)  ODOF=SIDOF+(2*SIDOF*XW1)                         CONO6810
      IF  (XW2.LE.0)  ODIF=SIDIF+(2*SIDIF*XW1)                         CONO6820
      ODOI=ODOF*12.                                                    CONO6830
      ODII=ODIF*12.                                                    CONO6840
      DELODF=0.                                                        CONO6850
      DELOD=DELODF                                                     CONO6860
      CSPO=SDDO*ODOF                                                   CONO6870
      CSPI=SDDI*ODIF                                                   CONO6880
      DELCSP=0.                                                        CONO6890
      RSPF=.866*(CSPO+CSPI)/2.                                         CONO6900
      RSP=RSPF*12.                                                     CONO6910
      IF  (RSPA.NE.0.)  RSP=RSPA                                       CONO6920
      RSPF=RSP/12.                                                     CONO6930
C                                                                      CONO6940
CCC      DETERMINE THE NUMBER OF TUBES IN THE CONDENSOR                CONO6950
CCC      ALL SECTORS ARE IDENTICAL IN GEOMETRY                         CONO6960
CCC      BEGINNING WITH THE INNERMOST ROW, CALCULATE THE NUMBER        CONO6970
CCC      OF ROWS IN THE CONDENSOR                                      CONO6980
C                                                                      CONO6990
      I=1                                                              CONO7000
      NOROWS=1                                                         CONO7010
      TNO=TNOTOT*(100.-PRCCLR)/100.                                    CONO7020
      RADIUS(1)=RADINS                                                 CONO7030
C                                                                      CONO7040
60    SID(I)=SIDOF                                                     CONO7050
      TNR=(ARCPR*RADIUS(I))/CSPO                                       CONO7060
      TNOS=TNOS+TNR                                                    CONO7070
C                                                                      CONO7080
CCC      CHECK TO ENSURE THAT THE NUMBER OF TUBES IN THE SECTOR        CONO7090
CC       HAS NOT EXCEEDED THE NUMBER OF TUBES AVAILABLE                CONO7100
C                                                                      CONO7110
      IF (TNOS.LT.(TNO/SECFLG)) GO TO 70                               CONO7120
      TNOS=TNOS-TNR                                                    CONO7130
      TNOC=TNOS*SECFLG                                                 CONO7140
      TDIFF=TNO-TNOC                                                   CONO7150
      TBNPR(I)=TDIFF/SECFLG                                            CONO7160
      PFILL=TBNPR(I)/TNR                                               CONO7170
      GO TO 80                                                         CONO7180
C                                                                      CONO7190
70    TPAR(I)=1./(CSPO*RSPF)                                           CONO7200
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      AOLFLW(I)=(CSPO-ODOF)*TNR                                          CON07210
      AOTFLW(I)=AOLFLW(I)*ALST                                           CON07220
      TBNPR(I)=TNR                                                       CON07230
      RADIUS(I+1)=RADIUS(I)+RSPF                                         CON07240
      I=I+1                                                              CON07250
      NOROWS=NOROWS+1                                                    CON07260
C                                                                        CON07270
CC       CHECK TO SEE THAT THE NUMBER OF ROWS DOESNOT EXCEED 199         CON07280
CC       BECAUSE 200 IS THE LIMIT FOR THE DIMENSIONS OF NUMEROUS ARRAYS  CON07290
C                                                                        CON07300
      IF (NOROWS.LT.100) GO TO 60                                        CON07310
      ERR1=TNO-(TNOS*SECFLG)                                             CON07320
      TNO=TNOS*SECFLG                                                    CON07330
      WRITE (6,640)                                                      CON07340
      NOROWS=NOROWS-1                                                    CON07350
      GO TO 90                                                           CON07360
C                                                                        CON07370
CC       IF LAST ROW IS INCOMPLETE, FIND ITS PERTINENT GEOMETRY          CON07380
C                                                                        CON07390
80    SDDL=(RADIUS(I)*ARCPR)/(ODOF*TBNPR(I))                             CON07400
      CSPL=SDDL*ODOF                                                     CON07410
      TPAR(I)=1./(CSPL*RSPF)                                             CON07420
      AOLFLW(I)=(CSPL-ODOF)*TBNPR(I)                                     CON07430
      AOTFLW(I)=AOLFLW(I)*ALST                                           CON07440
      TNOS=TNOS+TBNPR(I)                                                 CON07450
90    CONTINUE                                                           CON07460
      AHOLES=PI*(ODOF**2)*TNO/4.                                         CON07470
      ROWS=FLOAT(NOROWS)                                                 CON07480
      BNDRAD=RADINS+RSPF*(ROWS-1.)                                       CON07490
C                                                                        CON07500
C                                                                        CON07510
CC       THIS NEXT SUBROUTINE SWITCHES THE ARRAYS SO THE ARRAY VALUES    CON07520
CC       START WITH THE OUTSIDE ROW AND WORK TOWARDS THE CENTER.         CON07530
CC       THIS WILL MAKE THE GEOMETRY VALUES COMPATIBLE WITH THE REST     CON07540
CC       OF THE PROGRAM.                                                 CON07550
C                                                                        CON07560
      CALL SWITCH (RADIUS,NOROWS)                                        CON07570
      CALL SWITCH (SID,NOROWS)                                           CON07580
      CALL SWITCH (TBNPR,NOROWS)                                         CON07590
      CALL SWITCH (TPAR,NOROWS)                                          CON07600
      CALL SWITCH (AOLFLW,NOROWS)                                        CON07610
      CALL SWITCH (AOTFLW,NOROWS)                                        CON07620
C                                                                        CON07630
100   CONTINUE                                                           CON07640
C                                                                        CON07650
      AOTFLW(NOROWS+1)=ALST*(RADINS-SDI*ODII/24.)*PI/6.                  CON07660
C                                                                        CON07670
      IF (ISEC.EQ.1) SECANG(1)=PHI                                       CON07680
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      IF (ISEC.EQ.1) GO TO 110                                          CON07690
      FCWID=SECWID*(SECFLG-1.)                                          CON07700
      DO 110 I=1,ISEC                                                   CON07710
      SECA=(PHI-FCWID/2.)+SECWID*(I-1)                                  CON07720
      IF (SECA.GT.360.) SECA=SECA-360.                                  CON07730
  110 SECANG(I)=SECA                                                    CON07740
C                                                                       CON07750
      DUMMY=ALST*PI*SECWID*SECFLG/360.                                  CON07760
      BNDRA1=BNDRAD                                                     CON07770
      VOL1=DUMMY*BNDRA1**2                                              CON07780
      VOL1C=VCL1                                                        CON07790
C                                                                       CON07800
C     IF TNOTOT IS A DESIGN VARIABLE THEN THE INCREASE OF VOLUME  AND   CON07810
C     OUTSIDE BUNDLE RADIUS MUST BE A GRADUAL PROCESS AND NOT A STEP    CON07820
C     INCREASE OR DECREASE                                              CON07830
C                                                                       CON07840
      IF (IOPT.EQ.1) GO TO 120                                          CON07850
      RCORR=RSPF                                                        CON07860
      RCORR=RCORR*((1.-PFILL))                                          CON07870
      BNDRAD=BNDRAD-RCORR                                               CON07880
      VOL1=DUMMY*BNDRAD**2                                              CON07890
      VOL1C=VCL1                                                        CON07900
C                                                                       CON07910
  120 VOL2=DUMMY*(BNDRAD**2-RADINS**2)                                  CON07920
C                                                                       CON07930
C     COMPUTE THE AREA RATIO WHICH IS THE AREA OF TUBE HOLES DIVIDED    CON07940
C     BY THE TUBE SHEET AREA                                            CON07950
C                                                                       CON07960
      TSAREA=PI*(BNDRAD**2)*SECFLG*SECWID/360.                          CON07970
      ARATIO=AHOLES/TSAREA                                              CON07980
C                                                                       CON07990
C$-----------------                                                    CON08000
C ORC A4                                                                CON08010
C                    TEMP OUTPUT SECTION                                CON08020
C                                                                       CON08030
C               THIS SECTION FOR DEBUGGING AID                          CON08040
C                                                                       CON08050
C ZZZ ORC-A4                                                            CON08060
C-----------------                                                      CON08070
      ORCA4=0.                                                          CON08080
      IF (ORCA4.NE.1.) GO TO 150                                        CON08090
      WRITE (6,650)                                                     CON08100
      WRITE (6,660)                                                     CON08110
      WRITE (6,700) ODOF,ODIF,DELODF                                    CON08120
      WRITE (6,670)                                                     CON08130
      WRITE (6,700) CSPO,CSPI,DELCSP                                    CON08140
      WRITE (6,680)                                                     CON08150
      WRITE (6,700) RSPF,RSP,TNOS                                       CON08160
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      WRITE (6,690)                                                     CON08170
      WRITE (6,700) AHOLES,TSAREA,ARATIO                                CON08180
      WRITE (6,710)                                                     CON06190
      DO 130 I=1,NOROWS                                                 CON08200
130   WRITE (6,740) AOTFLW(I),RADIUS(I),TBNPR(I),TPAR(I)                CON08210
      WRITE (6,720)                                                     CON08220
      DO 140 I=1,ISEC                                                   CON08230
140   WRITE (6,730) SECANG(I)                                           CON08240
150   CONTINUE                                                          CON08250
C$-------------                                                         CON08260
C  ORC 5                                                              CON06270
C                          LOCATE BAFFLES                             CON08280
C                                                                     CON08290
C              THIS SECTION CALCULATES BAFFLE ANGULAR LOCATION         CON08300
C              BASED ON THE INPUT VALUES OF IBAF AND JBAF.            CON08310
C                                                                     CON08320
C         BAFA = BAFFLE LOCATIONS IN RADIANS MEASURED C-C WISE FROM VERT. CON08330
C         FCWI = ONE-HALF OF THE BUNDLE ANGULAR WIDTH IN RADIANS      CON08340
C         FCWID = FCWI EXPRESSED IN DEGREES OF ARC                    CON08350
C         IBAF = BAFFLE CONTROL VARIABLE                              CON08360
C              IBAF = -1 IMPLIES BAFFLES BETWEEN EACH SECTOR          CON08370
C              IBAF =  0 IMPLIS NO BAFFLES (SEE NOTE)                 CON08380
C              IBAF =  N IMPLIES N BAFFLES                            CON08390
C         IBAFT = NUMBER OF BAFFLES IN CONDENSER                      CON08400
C              IBAFT = ISEC + 1 FOR IBAF = -1                         CON08410
C              IBAFT = 2 FOR IBAF = 0                                 CON08420
C              IBAFT = N FOR IBAF = N                                 CON08430
C         ISEC = NUMBER OF SECTORS IN THE CONDENSER                   CON08440
C         JBAF = SECTOR NUMBERS OF THOSE SECTORS WHOSE COUNTER-CLOCKWISE CON08450
C                SIDE HAS A BAFFLE ATTACHED.                          CON08460
C         PHI = BUNDLE ORIENTATION ANGLE IN DEGREES OF ARC CLOCK-WISE CON08470
C               FROM VERTICLE.                                        CON08480
C         PHII = PHI EXPRESSED IN RADIANS                             CON08490
C         SECI = SECTOR ARC WIDTH IN RADIANS                          CON08500
C         SECWID = SECTOR ARC WIDTH IN DEGREES OF ARC                 CON08510
C                                                                     CON08520
C  ZZZ ORC-5                                                          CON08530
C---------------                                                      CON08540
      IBAFT=IBAF                                                      CON08550
      SECI=SECWID*PI/180.                                             CON08560
      FCWID=SECWID*SECFLG/2.                                          CON08570
      FCWI=FCWID*PI/180.                                              CON08580
      PHII=PHI*PI/180.                                                CON08590
      IF (IBAF) 160,200,180                                           CON08600
160   IBAFT=ISEC+1                                                    CON08610
      DO 170 I=1,IBAFT                                                CON08620
170   JBAF(I)=I                                                       CON08630
180   DO 190 I=1,IBAFT                                                CON08640
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      IT=JBAF(I)                                                        CON08650
190   BAFA(I)=PHII-FCWI+SECI*FLOAT(IT-1)                                CON08660
      GO TO 210                                                         CON08670
200   BAFA(1)=PHII-FCWI                                                 CON08680
      BAFA(2)=PHII+FCWI                                                 CON08690
      IBAFT=2                                                           CON08700
      JBAF(1)=1                                                         CON08710
      JBAF(2)=ISEC+1                                                    CON08720
210   CONTINUE                                                          CON08730
C$-------------                                                         CON08740
C ORC A5                                                                CON08750
C                       TEMP OUTPUT SECTION                             CON08760
C ZZZ ORC-A5                                                            CON08770
C---------------                                                        CON08780
      ORCA5=0.                                                          CON08790
      IF (ORCA5.NE.1) GO TO 240                                         CON08800
      WRITE (6,750)                                                     CON08810
      WRITE (6,760) IBAF,IBAFT                                          CON08820
      WRITE (6,770)                                                     CON08830
      DO 220 I=1,IBAFT                                                  CON08840
220   WRITE (6,780) I,JBAF(I)                                           CON08850
      WRITE (6,790)                                                     CON08860
      DO 230 I=1,IBAFT                                                  CON08870
      X=BAFA(I)*180./PI                                                 CON08880
230   WRITE (6,800) X,BAFA(I)                                           CON08890
240   CONTINUE                                                          CON08900
C$-------------                                                         CON08910
C ORC 6                                                                 CON08920
C                       LOCATE ACTIVE BAFFLE FOR EACH SECTOR            CON08930
C                                                                       CON08940
C ZZZ ORC-6                                                             CON08950
C---------                                                              CON08960
      DO 430 IS=1,ISEC                                                  CON08970
      SECA=SECANG(IS)*PI/180.                                           CON08980
      SEC=PI/2.-SECA                                                    CON08990
      IF ((SECA.GT.0.).AND.(SECA.LT.PI)) GO TO 270                      CON09000
      DO 250 I=1,IBAFT                                                  CON09010
      BAFAT=BAFA(I)                                                     CON09020
      IF (BAFAT.GT.SECA) GO TO 260                                      CON09030
250   CONTINUE                                                          CON09040
260   BAF=PI/2.-BAFAT                                                   CON09050
      IF ((BAFAT.GT.0.).AND.(SECA.LT.0.)) BAF=PI/2.                     CON09060
      GO TO 300                                                         CON09070
270   DO 280 I=1,IBAFT                                                  CON09080
      J=IBAFT+1-I                                                       CON09090
      BAFAT=BAFA(J)                                                     CON09100
      IF (BAFAT.LT.SECA) GO TO 290                                      CON09110
280   CONTINUE                                                          CON09120
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      BAF=PI/2.                                                          CON0$130
      GO TO 300                                                          CON09140
290   BAF=PI/2.-BAFAT                                                    CON0$150
300   CONTINUE                                                           CON09160
      IF (BAFAT.LT.0.) BAF=PI/2.                                         CON09170
C$-------------                                                          CON0$180
C ORC A6                                                                 CON09190
C                    TEMP OUTPUT SECTION                                 CON0$200
C                                                                        CON0$210
C ZZZ ORC-A6                                                             CON09220
C-------------                                                           CON09230
      ORCA6=C.                                                           CON09240
      IF (ORCA6.NE.1.) GO TO 310                                         CON09250
      WRITE (6,810)                                                      CON0$260
      WRITE (6,820)                                                      CON09270
      X=SEC*180./PI                                                      CON09280
      WRITE (6,830) IS,X,SEC                                             CON0$290
      X=BAF*180./PI                                                      CON09300
      WRITE (6,840) X,BAF                                                CON0$310
310   CONTINUE                                                           CON09320
C$-------------                                                          CON09330
C ORC 7                                                                  CON09340
C                    CALCULATE FLOODING FACTORS                          CON09350
C                                                                        CON0$360
C        AN = SUMMING RAGISTER FOR NO. OF TUBES                          CON09370
C        ANT = NO. OF TUBES OVER THE TARGET TUBE                         CON09380
C        BAF = ANGLE ABOUT HORIZONTAL OF 1ST BAFFLE ABOVE CURRENT SECTOR CON09390
C        DELODF = SEE ORC-4                                              CON09400
C        D1 = FARTHEST DIST FROM HORIZONTAL TO CURRENT ROW INTERSECTION   CON0$410
C        D2 = SHORTEST  "   "   "    "    "    "    "                   CON09420
C        IR = ROW NO. OF CURRENT TARGET TUB.                             CON09430
C        IS = SECTOR NO. OF CURRENT TARGET TUBE                          CON0$440
C        ITR = ROW NO. FOR 1ST ROW TO BE SUMMED IN UPPER QUADRANT        CON09450
C        I1 = ROW WHOSE CONTRIBUTION TO ANT IS BEING CALCULATED          CON09460
C        I2 = LOOP COUNTER IN UPPER QUADRANT CALCULATION                 CON09470
C        NOROWS = NO. OF ROWS IN THE CONDENSER                           CON09480
C        OD = TUBE OD IN ROW BEING CONSIDERED - FT                       CON0$490
C        ODOF = TUBE DIAMETER IN OUTERMOST (IR = 1) ROW OF TUBES         CON09500
C        RADIUS = RADIUS OF EACH TUBE ROW                                CON0$510
C        RSPF = ROW RADIAL SEPARATION - FT                               CON0$520
C        R1 = RADIUS OF UPPER OR LOWER BOUNDARY OF ROW I1                CON09530
C        SEC = ANGLE FROM HORIZONTAL OF CURRENT SECTOR MIDPOINT          CON09540
C        SECA= ANGLE FROM VERTICAL OF CURRENT SECTOR MIDPOINT            CON09550
C        TEST = TEST FOR VERTICAL BAFFLES                                CON09560
C        TPAR = TUBE DENSITY PER UNIT AREA PFOR EACH ROW - TUBES/FT**2   CON0$570
C        XC = HORIZONTAL DIST OR CURRENT TUBE FROM COND CENTER           CON09580
C        XCS = XC SQUARED                                                CON0$590
C        YC = VERTICAL (+/-) DIST OF CURRENT TUBE FROM COND CNTR - FT    CON0$600
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C          ZT = VERT DIST FROM TARGET TUBE TO BAFFLE INTERSECTION  -  FT   CON09610
C                                                                          CON09620
C ZZZ ORC-7                                                                CON09630
C--------------                                                            CON09640
      ORCA7=0.                                                             CON09650
      IF (ORCA7.EQ.1.) WRITE (6,860)                                       CON09660
      DO 420 IR=I,NOROWS                                                   CON09670
C     IF(IS.EQ.ISEC.AND.IR.GE.20)ORCA7 = 1.                                CON09680
      ITR=IR                                                               CON09690
      AN=0.                                                                CON09700
      OD=ODOF-DELODF*FLOAT(IR-1)                                           CON09710
      R1=RADIUS(IR)                                                        CON09720
      YC=R1*SIN(SEC)                                                       CON09730
      XC=R1*COS(SEC)                                                       CON09740
      XCS=XC*XC                                                            CON09750
      TEST=ABS(ABS(BAF)-PI/2.)                                             CON09760
      X=OD*12.                                                             CON09770
      IF (ORCA7.EQ.1.) WRITE (6,870) IR,IS                                 CON09780
      IF (ORCA7.EQ.1.) WRITE (6,880) X,R1,YC,XC,TEST                       CON09790
      IF (TEST.GT.1E-2) GO TO 320                                          CON09800
      ZT=1E10                                                              CON09810
      GO TO 330                                                            CON09820
320   ZT=XC*TAN(BAF)                                                       CON09830
330   XC=ABS(XC)                                                           CON09840
      IF (YC.GT.0.) GO TO 370                                              CON09850
      IF (ORCA7.EQ.1.) WRITE (6,890) ZT                                    CON09860
      D1=YC                                                                CON09870
      DO 340 I1=IR,NOROWS                                                  CON09880
      R1=RADIUS(I1)-RSPF/2.                                                CON09890
      IF (R1.LE.XC) GO TO 350                                              CON09900
      D2=-1.*SQRT(R1*R1-XCS)                                               CON09910
      IF (ORCA7.EQ.1.) WRITE (6,900) I1,R1,D2                              CON09920
      IF (D2.GT.ZT) GO TO 360                                              CON09930
      IF (ORCA7.EQ.1.) WRITE (6,910)                                       CON09940
      AN=AN+(D2-D1)/(RSPF*2.)                                              CON09950
      IF (ORCA7.EQ.1.) WRITE (6,920) D1,D2,AN                              CON09960
      D1=D2                                                                CON09970
340   CONTINUE                                                             CON09980
      D2=-D2                                                               CON09990
      IF (ORCA7.EQ.1.) WRITE (6,940)                                       CON10000
      IF (D2.GT.ZT) GO TO 410                                              CON10010
      ITR=NOROWS                                                           CON10020
      D1=D2                                                                CON10030
      IF (ORCA7.EQ.1.) WRITE (6,950)                                       CON10040
      GO TO 380                                                            CON10050
350   AN=AN-D1/(RSPF*2.)                                                   CON10060
      D1=0.                                                                CON10070
      ITR=I1                                                               CON10080
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      IF (ORCA7.EQ.1.) WRITE (6,930) AN,ITR                              CON10090
      GO TO 380                                                          CON10100
360   AN=AN+(ZT-D1)/(RSPF*2.)                                            CON10110
      IF (ORCA7.EQ.1.) WRITE (6,960)                                     CON10120
      GO TO 410                                                          CON10130
370   D1=YC                                                              CON10140
      IF (ORCA7.EQ.1.) WRITE (6,970) D1                                  CON10150
380   DO 390 I2=1,ITR                                                    CON10160
      I1=ITR-I2+1                                                        CON10170
      R1=RADIUS(I1)+RSPF/2.                                              CON10180
      D2=SQRT(R1*R1-XCS)                                                 CON10190
      IF (ORCA7.EQ.1.) WRITE (6,980) IR,I1,R1                            CON10200
      IF (ORCA7.EQ.1.) WRITE (6,990) D1,D2,ZT                            CON10210
      IF (D2.GT.ZT) GO TO 400                                            CON10220
      AN=AN+(D2-D1)/(RSPF*2.)                                            CON10230
      IF (ORCA7.EQ.1.) WRITE (6,1000) AN                                 CON10240
390   D1=D2                                                              CON10250
      GO TO 410                                                          CON10260
400   AN=AN+(ZT-D1)/(RSPF*2.)                                            CON10270
      IF (ORCA7.EQ.1.) WRITE (6,1010)                                    CON10280
410   NF=AN+1.0                                                          CON10290
      RNF=NF                                                             CON10300
      ANT(IR,IS)=RNF                                                     CON10310
      IF (ORCA7.EQ.1.) WRITE (6,1020) IS,IR,AN                           CON10320
420   CONTINUE                                                           CON10330
430   CONTINUE                                                           CON10340
      ORCA7=0.                                                           CON10350
      IF (ORCA7.NE.1.) GO TO 450                                         CON10360
      DO 440 I=1,NOROWS                                                  CON10370
440   WRITE (6,850) I,(ANT(I,J),J=1,ISEC)                                CON10380
450   CONTINUE                                                           CON10390
C$----------                                                            CON10400
C ORC 9                                                                 CON10410
C                    PUMPING POWER CALCULATION                          CON10420
C                                                                       CON10430
C        ALST = TUBE LENGTH   FT                                        CON10440
C        A1 = COEF IN FF CALCULATION                                    CON10450
C        B1 = EXP IN FF CALCULATION                                     CON10460
C        CBI = COOLANT SALT CONCENTRATION IN WT PRCNT                   CON10470
C        CMDOT = COOLANT MASS FLOW/TUBE IN EACH ROW  LBM/SEC            CON10480
C        CMTOT = TOTAL COOLANT MASS FLOW THROUGH CONDENSER LBM/SEC      CON10490
C        DELWP = HEADER PRESSURE DIFFERENCE  PSI                        CON10500
C        FF = TUBE FRICTION FACTORS                                     CON10510
C        HEAD = FT**2/SEC**                                             CON10520
C        SID = STORED INNER TUBE DIAMETER                               CON10530
C        TID = TEMPORARY VALUE FOR TUBE INNER DIAMETER                  CON10540
C        SLD = STORED (LENGTH/TUBE INNER DIAMETER) RATIO                CON10550
C        SLDO = SLD RATIO OF TUBES IN OUTER ROW                         CON10560
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C          SLDI = SLD RATIO OF TUBES IN INNER ROW                                CON10570
C          SLD = THE AVERAGE OF SLDO AND SLDI                                    CON10580
C          HLOSS = HEAD LOSS                                                     CON10590
C          REW = REYNOLDS # OF COOLANT                                           CON10600
C          REWO = REYNOLDS # OF TUBES IN THE OUTER ROW                           CON10610
C          REWI = REYNOLDS # OF TUBES IN INNER ROW                               CON10620
C          PHP = PUMPING POWER IN HP                                             CON10630
C          PHPCON = PUMPING POWER OF THE CONDENSER BUNDLE ONLY                   CON10640
C          DELWPC = PRESSURE LOSS THRU TUBES IN PSI                              CON10650
C          GFLOW = OVERALL COOLANT FLOW IN LBM/HR                                CON10660
C          RHOW = DENSITY OF COOLANT                                             CON10670
C          XMUW = VISCOSITY OF COOLANT                                           CON10680
C          VELBI = COOLING WATER VELOCITY IN FT/SEC                              CON10690
C                                                                                CON10700
C ZZZ ORC-9                                                                      CON10710
C--------------                                                                  CON10720
      ORCA9=0.                                                                   CON10730
      RHOW=ROEFN(CBI,STBI)                                                       CON10740
      XMUW=BMUFN(CBI,STBI)/3600.                                                 CON10750
      XNUW=XMUW/RHOW                                                             CON10760
      CMTOT=0.                                                                   CON10770
      IF ((GFLOW.GT.0.).OR.(VELBI.GT.0.)) GO TO 530                              CON10780
      HEAD=2.*DELWP*144.*SG/RHOW                                                 CON10790
      DO 520 IR=1,NOROWS                                                         CON10800
      IF (ORCA9.EQ.1.) WRITE (6,1030) IR                                         CON10810
      ITEM=IR-1                                                                  CON10820
      IF (ITEM.EQ.0) ITEM=1                                                      CON10830
      VG=VW(ITEM)                                                                CON10840
      IF (ORCA9.EQ.1.) WRITE (6,1040) IR,ITEM,VG                                 CON10850
      IENHAN=0                                                                   CON10860
      IF (NEI.EQ.0) GO TO 480                                                    CON10870
      DO 460 IT=1,NEI                                                            CON10880
      NRNI1=NRNI(IT)                                                             CON10890
      NRNI2=NRNI1+NETI(IT)-1                                                     CON10900
      IF (IR.GE.NRNI1.AND.IR.LE.NRNI2) GO TO 470                                 CON10910
  460 CONTINUE                                                                   CON10920
      GO TO 480                                                                  CON10930
  470 IENHAN=1                                                                   CON10940
      A1=BC(IT)                                                                  CON10950
      B1=BE(IT)                                                                  CON10960
  480 TID=SID(IR)                                                                CON10970
      SLD=ALST/TID                                                               CON10980
      IF (IR.EQ.1) SLDO=SLD                                                      CON10990
      IF (IR.EQ.NOROWS) SLDI=SLD                                                 CON11000
      IF (ORCA9.EQ.1.) WRITE (6,1050) TID,SLD,IR                                 CON11010
  490 REW=VG*TID/XNUW                                                            CON11020
      IF (ORCA9.EQ.1.) WRITE (6,1060) REW,TID,XNUW                               CON11030
      IF (IENHAN.EQ.1) GO TO 510                                                 CON11040
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      IF (REW.GE.51904.4) GO TO 500                                     CON11050
      A1=.3164                                                          CON11060
      B1=-.25                                                           CON11070
      GO TO 510                                                         CON11080
  500 A1=.184                                                           CON11090
      B1=-.2                                                            CON11100
  510 CONTINUE                                                          CON11110
      IF (ORCA9.EQ.1.) WRITE (6,1070) A1,B1,REW                         CON11120
      FF=A1*REW**(B1)                                                   CON11130
      HLOSS=(1.1+FF*SLD)                                                CON11140
      IF (ORCA9.EQ.1.) WRITE (6,1080) FF,SLD,HLOSS,HEAD                 CON11150
      VG1=SQRT(HEAD/HLOSS)                                              CON11160
      TEST=ABS(VG-VG1)/VG                                               CON11170
      IF (ORCA9.EQ.1.) WRITE (6,1090) TEST,VG,VG1                       CON11180
      VG=VG1                                                            CON11190
      IF (TEST.GT.0.01) GO TO 490                                       CON11200
      IF (IR.EQ.1) REWO=REW                                             CON11210
      IF (IR.EQ.NOROWS) REWI=REW                                        CON11220
      CMDOT(IR)=PI*TID**2*VG*RHOW/4.                                    CON11230
      VW(IR)=VG                                                         CON11240
  520 CMTOT=SECFLG*CMDOT(IR)*TBNPR(IR)+CMTOT                            CON11250
      PHP=CMTOT*DELWP*144./(RHOW*550.)                                  CON11260
      PHPCON=PHP                                                        CON11270
      DELWPC=DELWP                                                      CON11280
      GO TO 600                                                         CON11290
  530 A=0.                                                              CON11300
      DO 540 IR=1,NOROWS                                                CON11310
      TID=SID(IR)                                                       CON11320
      IF (IR.EQ.1) SLDO=ALST/TID                                        CON11330
      IF (IR.EQ.NOROWS) SLDI=ALST/TID                                   CON11340
  540 A=A+TID*TID*PI*TBNPR(IR)/4.                                       CON11350
      SLD=(SLDO+SLDI)/2.                                                CON11360
      TID=ALST/SLD                                                      CON11370
      IF (GFLOW.LE.0.) GO TO 550                                        CON11380
      VX=GFLOW/((RHOW*A*SECFLG)*3600.)                                  CON11390
      CMTOT=GFLOW/3600.                                                 CON11400
      GO TO 560                                                         CON11410
  550 CMTOT=VELBI*RHOW*A*SECFLG                                         CON11420
      VX=VELBI                                                          CON11430
  560 REW=VX*TID/XNJW                                                   CON11440
      IF (REW.GT.51904.4) GO TO 570                                     CON11450
      FF=.3164*REW**(-.25)                                              CON11460
      GO TO 580                                                         CON11470
  570 FF=.184*REW**(-.2)                                                CON11480
  580 DELWPC=(1.1+FF*SLD)*VX**2*RHOW/(2.*SG*144.)                       CON11490
      DO 590 IR=1,NOROWS                                                CON11500
      CMDOT(IR)=PI*SID(IR)**2*VX*RHOW/4.                                CON11510
  590 VW(IR)=VX                                                         CON11520
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      REWO=VX*SID(1)/XNUW                                                    CON11530
      REWI=VX*SID(NOROWS)/XNUW                                               CON11540
      HEAD=2.*DELWPC*144.*SG/RHOW                                            CON11550
      PHP=CMTOT*DELWPC*144./(RHOW*550.)                                      CON11560
      PHPCON=PHP                                                             CON11570
      DELWP=DELWPC                                                           CON11580
600   CONTINUE                                                               CON11590
      HFG=HFGFN(STSAT1)                                                      CON11600
      STB2ES=(WSI*HFG)/(CPB*CMTOT*3600.)+STBI                                CON11610
C$-------------                                                              CON11620
C  ORC A9                                                                   CON11630
C                    TEMP OUTPUT SECTION                                     CON11640
C  ZZZ ORC-A9                                                               CON11650
C-------------                                                               CON11660
      ORCA9=0.                                                               CON11670
      IF (ORCA9.NE.1.) GO TO 630                                             CON11680
      WRITE (6,1100)                                                         CON11690
      WRITE (6,1110) RHOW                                                    CON11700
      WRITE (6,1120) XMUW                                                    CON11710
      WRITE (6,1130) XNUW                                                    CON11720
      WRITE (6,1140) HEAD                                                    CON11730
      WRITE (6,1150) REW,FF                                                  CON11740
      WRITE (6,1160) DELWP                                                   CON11750
      WRITE (6,1170) SLDI,SLDO                                               CON11760
      WRITE (6,1180) REWI,REWO                                               CON11770
      WRITE (6,1190) CMTOT                                                   CON11780
      WRITE (6,1200) PHP                                                     CON11790
      WRITE (6,1210)                                                         CON11800
      DO 610 I=1,NOROWS                                                      CON11810
610   WRITE (6,1220) I,VW(I)                                                 CON11820
      DO 620 I=1,NOROWS                                                      CON11830
620   WRITE (6,1220) I,CMDOT(I)                                              CON11840
630   CONTINUE                                                               CON11850
C$-------------                                                              CON11860
C  ORC 10                                                                   CON11870
C                    CALL TO SECALC                                          CON11880
C  ZZZ ORC-10                                                               CON11890
C-------------                                                               CON11900
      CALL SECALC (ARCPR,DELODF,ODIF,ODOF)                                   CON11910
      RETURN                                                                 CON11920
640   FORMAT (1H0,46HTHE NUMBER OF ROWS EXCEEDS THE MAXIMUM ALLOWED)         CON11930
650   FORMAT (1H1,24HOUTPUT SECTION FOR ORC-4)                               CON11940
660   FORMAT (1H0,10HODOF      ,10HODIF      ,10HDELODF     )                CON11950
670   FORMAT (1H0,10HCSPO      ,10HCSPI      ,10HDELCSP     )                CON11960
680   FORMAT (1H0,10HRSPF      ,10HRSP       ,10HTNOS       )                CON11970
690   FORMAT (1H0,10HAHOLES    ,10HTSAREA    ,10HARATIO     )                CON11980
700   FORMAT (1H ,3F10.5)                                                    CON11990
710   FORMAT (1H0,10HAOTFLW    ,10HRADIUS    ,10HTBNPR      ,10HTPAR       CON12000
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     1 )                                                                        CON12010
  720  FORMAT (1HO,10HSECANG     )                                             CON12020
  730  FORMAT (1H ,F10.6)                                                      CON12030
  740  FORMAT (1H ,4F10.5)                                                     CON12040
  750  FORMAT (1H1,24HOUTPUT FOR SECTION ORC-5)                                CON12050
  760  FORMAT (1HO,7HIBAF  = ,I4,5X,8HIBAFT = ,I4)                             CON12060
  770  FORMAT (1HO,22HFOR I =   ;  JBAF(I) = )                                 CON12070
  780  FORMAT (1H ,3X,I4,8X,I4)                                                CON12080
  790  FORMAT (1HO,36HBAFFLE ANGLES IN DEGREES AND RADIANS)                    CON12090
  800  FORMAT (1H ,3X,F6.1,3X,F6.4)                                            CON12100
  810  FORMAT (1H1,24HOUTPUT FOR SECTION ORC-6)                                CON12110
  820  FORMAT (1HO,50HANGLES ARE MEASURED CNTR-CLCK WISE FROM HORIZONTAL)      CON12120
  830  FORMAT (1HO,16HCURRENT SECTOR =,I3,16H  ANGLE IN DEG =,F6.1,21H  ACON12130
     1NGLE  IN RADIANS =,F6.4)                                                CON12140
  840  FORMAT (1HO,32HANGLE OF ACTIVE BAFFLE IN DEG. =,F6.1,14H  IN RADIACON12150
     1NS =,F6.4)                                                              CON12160
  850  FORMAT (1H ,I3,2X,6(F5.2,2X))                                           CON12170
  860  FORMAT (1HO,28H***   OUTPUT FOR ORC-7   ***)                           CON12180
  870  FORMAT (1HO,5HROW =,I4,11H  SECTOR = ,I4)                               CON12190
  880  FORMAT (1H ,4HOD =,F6.4,10H  RADIUS =,F6.2,6H  YC =,F6.2,6H  XC =,CON12200
     1F6.2,8H  TEST =,E10.3)                                                  CON12210
  890  FORMAT (1HO,36HTARGET TUBE IN LOWER QUADRANT,  ZT =,F20.4)              CON12220
  900  FORMAT (1H ,15HLWR QUAD - ROW=,I3,5H  R1=,F7.3,5H  D2=,F7.3)            CON12230
  910  FORMAT (1H ,18HBAFFLE WAS NOT HIT)                                      CON12240
  920  FORMAT (1H ,15HSTILL LWR - D1=,F7.3,5H  D2=,F7.3,5H  AN=,F6.2)          CON12250
  930  FORMAT (1H ,34HPASSING INTO UPPER QUADRANT - AN =,F6.2,15H  CURRENCON12260
     1T ROW =,I4)                                                             CON12270
  940  FORMAT (1H ,30HMOVING THRU VOID TO UPPER QUAD)                          CON12280
  950  FORMAT (1H ,22HBAFFLE NOT HIT IN VOID)                                  CON12290
  960  FORMAT (1H ,28HBAFFLE HIT IN LOWER QUADRANT)                            CON12300
  970  FORMAT (1H ,35HTARGET TUBE IS IN UPPER QUAD - D1 =,F8.4)                CON12310
  980  FORMAT (1H ,37HCALCULATING IN UPPER QUAD - TRGET RW=,I4,12H  CALC  CON12320
     1ROW =,I4,11H  CORR RAD=,F8.4)                                           CON12330
  990  FORMAT (1H ,4HD1 =,F6.3,6H  D2 =,F6.3,6H  ZT =,E10.3)                   CON12340
 1000  FORMAT (1H ,34HUPPER QUAD - BAFFLE NOT HIT - AN =,F6.2)                 CON12350
 1010  FORMAT (1H ,23HUPPER QUAD - BAFFLE HIT)                                 CON12360
 1020  FORMAT (1HO,26H** FINAL FOR TARGET ** IS=,I4,4H IR=,I4,5H ANT=,F8.CON12370
     12)                                                                      CON12380
 1030  FORMAT (1H ,16HAT DO LOOP - IR=,I4)                                     CON12390
 1040  FORMAT (1H ,9HTEMP  IR=,I4,7H  ITEM=,I4,5H  VG=,E10.3)                  CON12400
 1050  FORMAT (1H ,16HABOVE 380 - TID=,E10.3,6H  SLD=,E10.3,5H  IR=,I4)        CON12410
 1060  FORMAT (1H ,16HBELOW 380 - REW=,E10.3,6H  TID=,E10.3,7H  XNUW=,E10CON12420
     1.3)                                                                     CON12430
 1070  FORMAT (1H ,12HAT 400 - A1=,E10.3,5H  B1=,E10.3,6H  REW=,E10.3)         CON12440
 1080  FORMAT (1H ,3HFF=,E10.3,5H SLD=,E10.3,7H HLOSS=,E10.3,6H HEAD=,E10CON12450
     1.3)                                                                     CON12460
 1090  FORMAT (1H ,5HTEST=,E10.3,5H  VG=,E10.3,6H  VG1=,E10.3)                 CON12470
 1100  FORMAT (1H1,16HOUTPUT FOR ORC-9)                                        CON12480
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 1110  FORMAT (1HO,8H   RHO =  ,E10.3,10H LBM/FT**3)                          CON12490
 1120  FORMAT (1H ,8H   MU  =  ,E10.3,11H LBM/SEC-FT)                         CON12500
 1130  FORMAT (1H ,8H   NU  =  ,E10.3,10H FT**2/SEC)                          CON12510
 1140  FORMAT (1H ,8H   HEAD=  ,E10.3,13H FT**2/SEC**2)                       CON12520
 1150  FORMAT (1H ,8H   REW =  ,E10.3,3X,6HFF   = ,E10.3)                     CON12530
 1160  FORMAT (1H ,8HDELWP =  ,E10.3,4H PSI)                                  CON12540
 1170  FORMAT (1H ,39HLENGTH TO DIAMETER RATIO - INSIDE ROW =,F6.2,16H        CON12550
      1OUTSIDE ROW =,F6.2)                                                    CON12560
 1180  FORMAT (1H ,27HREYNOLDS NO. - INSIDE ROW =,E10.3,15H  OUTSIDE ROW     CON12570
      1=,E10.3)                                                               CON12580
 1190  FORMAT (1H ,24HCOOLANT MASS FLOW RATE =,F15.3,8H LBM/SEC)              CON12590
 1200  FORMAT (1H ,24HPUMPING POWER REQUIRED =,F10.2,3H HP)                   CON12600
 1210  FORMAT (1H ,37HCOOLANT VELOCITY IN EACH ROW - FT/SEC)                  CON12610
 1220  FORMAT (1H ,I4,3X,F10.3)                                               CON12620
       END                                                                    CON12630
C                                                                            CON12640
C*****************************************************************************CON12650
C*****************************************************************************CON12660
C                                                                            CON12670
      SUBROUTINE SECALC (ARCPR,DELODF,ODIF,ODCF)                             CON12680
C-------------                                                               CON12690
C SEC 1                                                                      CON12700
C                    SUBROUTINE SECALC                                       CON12710
C                                                                            CON12720
C              SUBROUTINES CALLED BY SECALC                                  CON12730
C          HETTRN                                                            CON12740
C                                                                            CON12750
C              FUNCTION ROUTINES CALLED BY SECALC                            CON12760
C        , TSATFN , VGFN , HFGFN , CPAFN ,                                   CON12770
C                                                                            CON12780
C                                                                            CON12790
C ZZZ SEC-1                                                                  CON12800
C-------------                                                               CON12810
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,     CON12820
     1RADINS,REWI,REWO,SDOI,SDOO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNOTU    CON12830
     2T,BNDRAC,ARATIO,ODII,ODOI,SDOC,VLCMAX,PRCCLR                           CON12840
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON12850
     1TSAT1,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON12860
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON12870
     3,WSI,PFILL                                                             CON12880
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMDOT(10CON12890
     10)                                                                     CON12900
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNG,VEL2,FR                   CON12910
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,ACC,SUMQC,SDIC,SDOC,UBARW,SMWBC,CON12920
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AGT,BUNWT,AVTBI,AVTB2,WTSTC,VOLC CON12930
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEFCON12940
     1F(100,15),PMIX(100,15),PSAT(100,15),QOA(100,15),RC(100,15),ROUT(10CON12950
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)CON12960
     3,VNRE(100,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WS(100,15CON12970
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     4),WSP(15)                                                                CON12970
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST                                CON12980
      COMMON /COOL1/ VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100CON12990
     1),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),CON13000
     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QDAC(100),CCON13010
     3UMDPC(100)                                                               CON13020
      COMMON /COOL/ IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,TCON13030
     1B2C,ENHIC,ENHOC,ENHFC,SHWINC,WBC                                         CON13040
      DIMENSION C(15)                                                          CON13050
C$-------------                                                               CON13060
C  SEC 2                                                                      CON13070
C                    INITIALIZE :OLD ORC 8,9                                 CON13080
C                                PART - 1                                    CON13090
C                                                                            CON13100
C         ALST = TUBE LENGTH  FT                                             CON13110
C         AMOLNC = TOTAL MOLES OF N/C GAS ENTERING CONDENSER                 CON13120
C         AMOLSS =  MOLES OF STM  ENTERING COND                              CON13130
C         AMOLST = SUM OF MOLES OF STM AND N/C  ENTERING COND                CON13140
C         AMWNC = MOLECULAR WEIGHT OF N/C                                    CON13150
C         ANT = TOTAL NO OF TUBE IN 360 DEG COND                             CON13160
C         ARAT = RATIO OF OUTSIDE ROW MIN FLOW AREA TO SECTOR FACE AREA      CON13170
C         ARCPR = CIRCUMFERENTIAL ARC LENGTH PER UNIT RADIUS                 CON13180
C         AOTFLW = AREA OPEN TO FLOW IN A ROW OF TUBES IN A SECTOR FT**2     CON13190
C         BNDRAD = TUBE BUNDLE OD  FT                                        CON13200
C         DELODF = CHANGE IN TUBE OD PER ROW  FT                             CON13210
C         DELP12 = ENTRANCE STM PRESS LOSS  PSI                              CON13220
C         DELP23 = STM PRESS LOSS AS STM IS ACCEL INTO FIRST ROW  PSI        CON13230
C         G2 =                                                               CON13240
C         HFG = STEAM LATENT HEAT  OF VAPORIZATION  BTU/LBM                  CON13250
C         NOROWS = NO. OF ROWS IN THE CONDENSER                              CON13260
C         ODOF = TUBE OD, OUTSIDE ROW  FT                                    CON13270
C         ODIF = TUBE OD, INSIDE ROW  FT                                     CON13280
C         ODOI = TUBE OD, OUTSIDE ROW  IN                                    CON13290
C         ODII = TUBE OD, INSIDE ROW  IN                                     CON13300
C         PMIX1 = PRESS OF STM - N/C MIXTURE ENERING COND  PSIA              CON13310
C         PSAT1 = ENTERING STEAM SAT PRESS PSIA                              CON13320
C         PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE      CON13330
C           CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET            CON13340
C           COOLANT TEMPERATURE. THE RESULT IS 0 HEAT TRANSFER               CON13350
C         RADINS = BUNDLE VOID RADIUS  FT                                    CON13360
C         ROWS = NO OF ROWS IN THE CONDENSER                                 CON13370
C         SECFAR = FACE AREA FOR ONE SECTOR                                  CON13380
C         SECFLG = NO. OF SECTORS IN THE CONDENSER MODEL                     CON13390
C         SMTB1 = ROW BY ROW SUM OF (COOLANT INLET TEMP * FLOW RATE)         CON13400
C         SMWB = ROW BY ROW SUM OF COOLANT FLOW                              CON13410
C         SMTB2 = ROW BY ROW SUM OF (COOLANT OUTLET TEMP * FLOW RATE)        CON13420
C         SUMQ = ROW BY ROW SUM OF HEAT DUTY ON TUBES                        CON13430
C         SG = GRAVITY FACTOR  32.2                                          CON13440
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C          STSAT1 = ENTERING STM SAT TEMP   F                                  CON13450
C          SVMIX1 = ENTERING MIXTURE SPECIFIC VOL   FT**3/LBM                  CON13460
C          SVNC1 = ENTERING N/C GAS SPECIFIC VOL   FT**3/LBM                   CON13470
C          TSAT1 = ENTERING STEAM SATURATION TEMP   R                          CON13480
C          WGAS = N/C FLOW TO EACH SECTOR   LBM/HR                             CON13490
C          WNCI = N/C GAS FLOW TO CONDENSER LBM/HR                             CON13500
C          WNCIR = RATIO OF MASS FLOW OF N/C TO MASS FLOW OF STEAM             CON13510
C          WS  = STEAM FLOW TO EACH SECTOR   LBM/HR                            CON13520
C          WSI = TOTAL STM FLOW TO CONDENSER LBM/HR                            CON13530
C          VEL1 = MIXTURE VELOCITY PRIOR TO ENTERING FIRST ROW  FT/SEC         CON13540
C          VEL2 = MIXTURE VELOCITY IN FIRST ROW OF TUBES  FT/SEC               CON13550
C          IVNOC = THE NUMBER OF VERTICAL TUBES IN THE COOLER                  CON13560
C          IHNOC = THE NUMBER OF HORIZONTAL TUBES IN THE COOLER                CON13570
C          HTCLR = THE HEIGHT OF THE COOLER                                    CON13580
C          VG1 = ENTERING STM SPECIFIC VOL   FT**3/LBM                         CON13590
C                                                                              CON13600
C ZZZ SEC-2                                                                    CON13610
C--------------                                                                CON13620
      ROWS=FLOAT(NOROWS)                                                       CON13630
      TNOC=0.                                                                  CON13640
      IVNOC=1                                                                  CON13650
      IF (PRCCLR.EQ.0.0) GO TO 10                                              CON13660
C                                                                              CON13670
CCC   COMPUTE THE NUMBER OF VERTICAL AND HORIZONTAL ROWS IN THE COOLER         CON13680
CCC   IF THERE IS ONE                                                          CON13690
C                                                                              CON13700
      SODC=SODI                                                                CON13710
      TNOC=(PRCCLR/(100.-PRCCLR))*TNO                                          CON13720
      HTCLR=BNDRAD-RADINS                                                      CON13730
      VNOC=(HTCLR/(SODC*ODIF*0.886))+1.                                        CON13740
      IHNOC=TNOC/VNOC                                                          CON13750
      HNOC=FLOAT(IHNOC)                                                        CON13760
      VNOC=TNOC/HNOC                                                           CON13770
      IVNOC=VNOC+.5                                                            CON13780
      VNOC=FLOAT(IVNOC)                                                        CON13790
C                                                                              CON13800
10    KSTOP=NCROWS+1                                                           CON13810
      SECFLG=FLOAT(ISEC)                                                       CON13820
      WNCI=WSI*WNCIR                                                           CON13830
      IPLOOP=0                                                                 CON13840
      WSAVE=(WSI+WNCI)/SECFLG                                                  CON13850
C                                                                              CON13860
CCC                                                                            CON13870
CCC                    INITIALIZE TEST VARIABLES TO 0                          CON13880
C                                                                              CON13890
20    CONTINUE                                                                 CON13900
      STMSUM=0.                                                                CON13910
      WTSAV=0.                                                                 CON13920
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      STBIR=STBI+459.69                                                    CON13930
      PTLIM=PSATFN(STBIR)                                                  CON13940
      TSAT1=STSAT1+459.69                                                  CON13950
      PSAT1=PSATFN(TSAT1)                                                  CON13960
      AMOLNC=WNCI/AMWNC                                                    CON13970
      HFG=HFGFN(STSAT1)                                                    CON13980
      AMOLSS=WSI/18.015                                                    CON13990
      AMOLST=AMOLSS+AMOLNC                                                 CON14000
      PMIX1=PSAT1*(AMOLST/AMOLSS)                                          CON14010
      VG1=VGFN(TSAT1,PMIX1)                                                CON14020
      SVNC1=10.729*TSAT1/(AMWNC*PMIX1)                                     CON14030
      SVMIX1=1.0/(AMOLSS/(AMOLST*VG1)+AMOLNC/(SVNC1*AMOLST))               CON14040
      G2=288.0*SG*SVMIX1                                                   CON14050
      SMTBI=0.0                                                            CON14060
      SMWB=0.0                                                             CON14070
      WB=0.                                                                CON14080
      SMTB2=0.0                                                            CON14090
      SUMQ=0.0                                                             CON14100
      CUMDRY=0.                                                            CON14110
      SUBFLO=0.                                                            CON14120
      NBAD=0                                                               CON14130
      WCNDAV=0.                                                            CON14140
      SUBAVE=0.                                                            CON14150
C                                                                          CON14160
C                                                                          CON14170
C     COMPUTE THE PRESSURE LOSSES AT THE ENTRANCE OF THE SECTOR            CON14180
C                                                                          CON14190
      SECFAR=ARCPR*(BNDRAD+ODOF/2.)*ALST                                   CON14200
      ARAT=AOTFLW(1)/SECFAR                                                CON14210
      VEL1=(WSI+WNCI)*SVMIX1/(3600.0*SECFAR*SECFLG)                        CON14220
      VEL2=VEL1/ARAT                                                       CON14230
      IF (ARAT-0.715) 30,30,40                                             CON14240
30    DELP12=0.4*(1.25-ARAT)*VEL2**2/G2                                    CON14250
      GO TO 50                                                             CON14260
40    DELP12=0.75*(1.0-ARAT)*VEL2**2/G2                                    CON14270
50    DELP23=(VEL2**2-VEL1**2)/G2                                          CON14280
C$-------------                                                            CON14290
C  SEC A2                                                                  CON14300
C                        TEMP OUTPUT SECTION                               CON14310
C                                                                          CON14320
C  ZZZ SEC-A2                                                              CON14330
C---------------                                                           CON14340
      SECA2=0.                                                             CON14350
      IF (SECA2.EQ.0.) GO TO 70                                            CON14360
      DO 60 I=1,ISEC                                                       CON14370
      WRITE (6,610)                                                        CON14380
      WRITE (6,620)                                                        CON14390
      WRITE (6,700) WSI,WNCI                                               CON14400
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      WRITE (6,630)                                                     CON14410
      WRITE (6,700) WS(1,I),WGAS(I)                                     CON14420
      WRITE (6,640)                                                     CON14430
      WRITE (6,700) HFG,AOTFLW(I)                                       CON14440
      WRITE (6,650)                                                     CON14450
      WRITE (6,700) TSAT1,STSAT1                                        CON14460
      WRITE (6,660)                                                     CON14470
      WRITE (6,700) PSAT1,PMIX1                                         CON14480
      WRITE (6,670)                                                     CON14490
      WRITE (6,710) AMOLNC,AMOLSS,AMOLST                                CON14500
      WRITE (6,680)                                                     CON14510
      WRITE (6,700) SVNC1,SVMIX1                                        CON14520
      WRITE (6,690)                                                     CON14530
      WRITE (6,700) VG1,G2                                              CON14540
      WRITE (6,720)                                                     CON14550
      WRITE (6,750) SECFAR,ARAT                                         CON14560
      WRITE (6,730)                                                     CON14570
      WRITE (6,750) VEL1,VEL2                                           CON14580
      WRITE (6,740)                                                     CON14590
60    WRITE (6,750) DELP12,DELP23                                       CON14600
70    CONTINUE                                                          CON14610
C$-------------                                                         CON14620
C  SEC 3                                                                CON14630
C                    DO LOOP ON SECTORS - HEREAFTER REFERRED TO AS       CON14640
C                                    MAIN SECTOR LOOP                   CON14650
C                                                                       CON14660
C              PROGRAM ENTERS SEC-3 FROM SEC-2 AND ALWAYS EXITS         CON14670
C              TO SEC-4.                                                CON14680
C                                                                       CON14690
C              THIS SECTION STARTS THE J LOOP AND ESTABLISHES           CON14700
C              SOME OF THE INITIAL CONDITIONS FOR THE FIRST             CON14710
C              ROW OF THE CURRENT SECTOR CALCULATION.                   CON14720
C                                                                       CON14730
C              SUBSRIPTED QUANTITIES ARE SET UP AS                      CON14740
C                VARIABLE (SUB1,SUB2) WHERE SUB1 IS                     CON14750
C                THE ROW NUMBER, AND SUB2 IS THE SECTOR                 CON14760
C                NUMBER.                                                CON14770
C                                                                       CON14780
C         PMIX = PRESSURE OF STM-N/C MIXTURE                            CON14790
C         PMIX1 = PRESSURE OF STM-N/C MIXTURE ENTERING SECTOR           CON14800
C         J=DUMMY VARIABLE REPRESENTING SECTOR NUMBER                   CON14810
C         SECFLG = NO OF SECTORS IN THE CONDENSER                       CON14820
C         DELP = PRESSURE DROP ACROSS A SECTOR                          CON14830
C         DELP12 = ENTRANCE PRESSURE LOSS IN THE CONDENSER              CON14840
C         DELP23 = PRESSURE LOSS AT BUNDLE DUE TO VELOCITY CHANGE       CON14850
C         AMOLSS = MOLES OF STEAM ENTERING THE CONDENSER                CON14860
C         AMOLST = TOTAL MOLES OF STEAM AND N/C ENTERING CONDENSER      CON14870
C         AMOLNC = MOLES OF N/C GASSES ENTERING THE CONDENSER           CON14880
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C          PSAT = SATURATED STEAM PRESS                                          CON14890
C          PAL = SAME AS PSAT                                                    CON14900
C          PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE        CON14910
C            CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET              CON14920
C            COOLANT TEMPERATURE. THE RESULT IS O HEAT TRANSFER                  CON14930
C          TAL = SAT STEAM TEMP IN RANKIN                                        CON14940
C          STSAT = STAT STEAM TEMP F                                             CON14950
C          VG = SPECIFIC VOLUME OF STEAM FT**3/LB                                CON14960
C          AMWNC = MOLECULAR WEIGHT OF N/C GASSES                                CON14970
C          VNC = SPECIFIC VOLUME OF N/C GAS FT**3/LB                             CON14980
C          VMIX = SPECIFIC VOLUME OF STEAM AND N/C GASSES IN MIXTURE             CON14990
C          WS = STEAM FLOW TO A ROW OF TUBES IN A SECTOR LB/HR                   CON15000
C          WGAS = FLOW OF N/C TO A SECTOR LB/HR                                  CON15010
C          WNC = SAME AS WGAS                                                    CON15020
C          AOTFLW = AREA OPEN TO FLOW IN A BANK OF TUBES                         CON15030
C          VEL = STEAM-N/C MIXTURE VELOCITY IN A ROW OF TUBES                    CON15040
C                                                                                CON15050
C  ZZZ SEC-3                                                                     CON15060
C-------------                                                                   CON15070
      DO 390 J=1,ISEC                                                           CON15080
C     INITIALIZE SECTOR TEST VARIABLES                                          CON15090
C                                                                               CON15100
      WTST(J)=0.                                                                CON15110
      PTST(J)=0.                                                                CON15120
      CHECK1=0.                                                                 CON15130
      CHECK2=0.                                                                 CON15140
      SUBRAT=0.                                                                 CON15150
      TUBDRY=0.                                                                 CON15160
      IIII=0                                                                    CON15170
      DELP(J)=0.                                                                CON15180
      DELPP=0.                                                                  CON15190
      DELPTP=0.                                                                 CON15200
      PMIX(1,J)=PMIX1-DELP12-DELP23                                             CON15210
      PSAT(1,J)=PMIX(1,J)*(AMOLSS/AMOLST)                                       CON15220
C                                                                               CON15230
C     CHECK TO SEE IF SATURATION PRESSURE INTO THE SECTOR IS BELOW THE           CON15240
C     SATURATION PRESSURE CORRESPONDING TO THE COOLANT INLET TEMPERATURE         CON15250
C     (PTLIM). STEAM SATURATION PRESSURE CAN ONLY FALL TOO LOW DUE TO            CON15260
C     EXCESSIVE ENTRANCE PRESSURE LOSSES (DELP12,DELP23)                        CON15270
C                                                                               CON15280
      IF (PSAT(1,J).GT.PTLIM) GO TO 90                                          CON15290
C                                                                               CON15300
C     IF PSAT<PTLIM THEN DUMMY VALUES MUST BE INSERTED FOR PSAT,PMIX            CON15310
C     AND DELPP IN ORDER TO KEEP THE PROGRAM RUNNING. A VALUE FOR PTST          CON15320
C     IS ALSO DETERMINED.                                                       CON15330
C                                                                               CON15340
      PTST(J)=PSAT(1,J)-PTLIM-NOROWS                                            CON15350
      RTG=FLOAT(NOROWS+1)                                                       CON15360
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      NRWSP3=NOROWS+1                                                    CON15370
      DELPP=PTLIM/(RTG+1.)                                               CON15380
      CHECK2=-2.                                                         CON15390
      DO  80  M=1,NRWSP3                                                 CON15400
      PSAT(M,J)=PTLIM-(M-1)*DELPP                                        CON15410
80    CONTINUE                                                           CON15420
      PMIX(1,J)=PSAT(1,J)/(AMOLSS/AMOLST)                                CON15430
C                                                                        CON15440
90    PAL=PSAT(1,J)                                                      CON15450
      TAL=TSATFN(PAL)                                                    CON15460
      STSAT(1,J)=TAL-459.69                                              CON15470
      VG=VGFN(TAL,PMIX(1,J))                                             CON15480
      VNC=(10.729*TAL)/(AMWNC*PMIX(1,J))                                 CON15490
      VMIX=1.0/((AMOLSS/(VG*AMOLST))+(AMOLNC/(VNC*AMOLST)))              CON15500
      VEL(1,J)=(WS(1,J)+WGAS(J))*VMIX/(3600.0*AOTFLW(1))                 CON15510
      WNC=WGAS(J)                                                        CON15520
      AMOLSC=WNC/AMWNC                                                   CON15530
C$-------------                                                          CON15540
C  SEC A3                                                                CON15550
C                    TEMP OUTPUT SECTION                                 CON15560
C                                                                        CON15570
C  ZZZ SEC-A3                                                            CON15580
C-------------                                                           CON15590
      SECA3=0.                                                           CON15600
      IF  (SECA3.NE.1.) GO TO 100                                        CON15610
      WRITE  (6,760)  J                                                  CON15620
      WRITE  (6,770)  PMIX(1,J),PSAT(1,J)                                CON15630
      WRITE  (6,780)  STSAT(1,J),TAL                                     CON15640
      WRITE  (6,790)  VG,VNC,VMIX                                        CON15650
      WRITE  (6,800)  VEL(1,J)                                           CON15660
100   CONTINUE                                                           CON15670
C$-------------                                                          CON15680
C  SEC 4                                                                 CON15690
C                    DO LOOP ON ROWS - HEREAFTER REFERRED TO AS          CON15700
C                                 MAIN ROW LOOP                          CON15710
C                                                                        CON15720
C              THIS SECTION IS INSIDE THE MAIN SECTOR LOOP.  IT          CON15730
C              INITIALIZES SOME VARIABLES PRIOR TO CALLING HETTRN        CON15740
C              IN SEC-5.                                                 CON15750
C                                                                        CON15760
C         I = ROW NUMBER                                                 CON15770
C         IL = ROW NUMBER DUMMY VARIABLE                                 CON15780
C         AXO = AREA OPEN TO FLOW IN A ROW OF TUBES  FT**2               CON15790
C         AOTFLW = SAME AS AXO                                           CON15800
C         L = SECTOR NUMBER                                              CON15810
C         J = SECTOR NUMBER DUMMY VARIABLE                               CON15820
C         NOROWS = NUMBER OF ROWS OF TUBES IN A SECTOR                   CON15830
C         DELODF = CHANGE IN TUBE OD / ROW  FT                           CON15840
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C          OD = TUBE OD    FT                                                    CON15850
C          ODOF = TUBE CD, OUTSIDE ROW   FT                                      CON15860
C          XW = TUBE WALL THICKNESS    FT                                        CON15870
C          SDW = LOG MEAN TUBE THICKNESS   FT                                    CON15880
C          AXI = TUBE INNER CROSS-SECTIONAL AREA  FT**2                          CON15890
C          AI = TUBE INNER SURFACE AREA  FT**2                                   CON15900
C          AO = TUBE OUTER SURFACE AREA  FT**2                                   CON15910
C          AW = LOG MEAN TUBE SURFACE AREA  FT**2                                CON15920
C          SHWINV = INVERSE OF WALL HEAT X-FER COEF  HR-FT**2-F/BTU              CON15930
C          PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE        CON15940
C            CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET              CON15950
C            COOLANT TEMPERATURE. THE RESULT IS 0 HEAT TRANSFER                  CON15960
C          SKW = TUBE THERMAL CONDUCTIVITY   BTU-FT/HR-FT**2-F                   CON15970
C          TID = TUBE INNER DIAMETER  FT                                         CON15980
C          WST = STEAM FLOW TO A ROW IN A SECTOR  LBM/HR                         CON15990
C                                                                                CON16000
C  ZZZ SEC-4                                                                     CON16010
C---------------                                                                 CON16020
      DO 380 IL=1,NOROWS                                                        CON16030
      I=IL                                                                      CON16040
      L=J                                                                       CON16050
      IJX=0                                                                     CON16060
      LQ=0                                                                      CON16070
      WB=CMDOT(I)*3600.                                                         CON16080
      AXO=AOTFLW(I)                                                             CON16090
      OD=ODOF-DELODF*FLOAT(IL-1)                                                CON16100
      TID=SID(IL)                                                               CON16110
      XW=(OD-TID)/2.                                                            CON16120
      AI=ALST*PI*TID                                                            CON16130
      AO=ALST*PI*OD                                                             CON16140
      AXI=PI*(TID/2.)**2                                                        CON16150
      SDW=(OD-TID)/ALOG(OD/TID)                                                 CON16160
      AW=ALST*PI*SDW                                                            CON16170
      SHWINV=(AO*XW)/(SKW*AW)                                                   CON16180
      WST=WS(IL,J)                                                              CON16190
C*****                                                                          CON16200
      IF (WST.LE.0) WRITE (6,600) J,IL                                          CON16210
C$---------------                                                               CON16220
C  SEC A4                                                                       CON16230
C                    TEMP OUTPUT SECTION                                        CON16240
C                                                                               CON16250
C  ZZZ SEC-A4                                                                   CON16260
C---------------                                                                CON16270
      SECA4=0.                                                                  CON16280
      IF (SECA4.NE.1) GO TO 110                                                 CON16290
      WRITE (6,810) IL                                                          CON16300
      WRITE (6,820) AI,AO                                                       CON16310
      WRITE (6,830) TID,AXI                                                     CON16320
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      WRITE (6,840) SDW,AW                                                  CON16330
      WRITE (6,850) SHWINV                                                  CON16340
110   CONTINUE                                                              CON16350
C-----                                                                      CON16360
C SEC 5                                                                     CON16370
C                    CALL TO HETTRN AND PRSDRP                              CON16380
C                                                                           CON16390
C               THIS SECTION INSIDE BOTH MAIN ROW AND SECTOR LOOPS          CON16400
C                                                                           CON16410
C                                                                           CON16420
C         STSAT = STEAM SATURATION TEMP  F                                  CON16430
C         ANT = TARGET TUBE LOCATION IN VERTICAL RCW                        CON16440
C         WS = STEAM FLOW TO A ROW OF A SECTOR   LBM/HR                     CON16450
C         WNC = N/C FLOW TO A ROW OF A SECTOR   LBM/HR                      CON16460
C         UN = OVERALL HEAT TRANSFER COEF FOR ONE ROW OF TUBES IN A SECT.   CON16470
C         ALMTD = LMTD FOR A ROW IN A SECTOR  F                             CON16480
C         HOMCI = STSAT - COOLANT INLET TEMP                                CON16490
C         HOMCO = STSAT - COOLANT OUTLET TEMP                               CON16500
C         STFO = AVE TEMP OF OUTER TUBE FILM                                CON16510
C         SHI = INTERNAL TUBE FILM HEAT TRANSFER COEF.                      CON16520
C         SHN = EXTERNAL TUBE FILM HEAT TRANSFER COEF                       CON16530
C         RC = RATIO OF N/C GAS TO STM AT ONE ROW OF TUBES                  CON16540
C         ROUT = EXTERNAL HEAT TRANSFER COEF                                CON16550
C         AXO = AREA OPEN TO FLOW IN A ROW OF TUBES  FT**2                  CON16560
C         VNRE = REYNOLDS NUMBER ON VAPOR SIDE AT A ROW IN A SECTOR         CON16570
C         DUMMY = NUSSELT NUMBER                                            CON16580
C         VPSHH = OUTLET COOLANT TEMP  F                                    CON16590
C         HEFF = N/C GAS FILM HEAT TRANSFER COEF                            CON16600
C         L = SECTOR NUMBER                                                 CON16610
C         HFG = STEAM LATENT HEAT OF VAPORIZATION  BTU/LBM                  CON16620
C         WCND = CONDENSATE FROM ONE ROW OF TUBES IN A SECTOR  LBM/HR       CON16630
C         AO = OUTER SURFACE AREA OF A TUBE  FT**2                          CON16640
C         PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE     CON16650
C           CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET           CON16660
C           COOLANT TEMPERATURE. THE RESULT IS O HEAT TRANSFER               CON16670
C         TBNPR = NUMBER OF TUBES IN A GIVEN ROW OF ASECTOR                 CON16680
C         TAL = SATURATED STEAM TEMP  R                                     CON16690
C         VMIX = SPECIFIC VOLUME OF STM-N/C MIXTURE  FT**3/LBM              CON16700
C         SDO = TUBE OD  FT                                                 CON16710
C         VPSH = FRICTION FACTOR USED IN PRESSURE DROP CALC                 CON16720
C         DELPTP = PRESS DROP ACROSS A ROW OF TUBES  PSI                    CON16730
C         ENHF = PRESSURE DROP FRICTION FACTOR ENHANCEMENT                  CON16740
C         ENHF = PRESS DROP FRICTION FACTOR ENHANCEMENT FACTOR, STM SIDE.   CON16750
C                                                                           CON16760
C ZZZ SEC-5                                                                 CON16770
C-----------                                                                CON16780
C                                                                           CON16790
C     CHECK TO ENSURE THAT THE SATURATION PRESSURE IN AN EARLIER ROW         CON16800
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C       CALCULATION HAS NOT DROPPED BELOW THE SATURATION PRESSURE          CON16810
C       CORRESPONDING TO THAT OF THE INLET COOLANT TEMPERATURE (PTLIM) FOR CON16820
C       A GIVEN SECTOR. IF IT HAS, CHECK2<0 AND WE SKIP HETTRN CALCS SINCE CON16830
C       DUMMY VARIABLES HAVE BEEN INSERTED FOR PSAT                        CON16840
C                                                                          CON16850
        IF (CHECK2.LT.0) GO TO 120                                         CON16860
C                                                                          CON16870
        CALL HETTRN (ALST,AXO,I,L,OD,WB,SHWINV,STSAT(I,L),TID,WNC,WST,ALMT CON16880
       1D(I,L),ENHF,HEFF(I,L),HOMCI,HOMCO,RC(I,L),ROUT(I,L),SHI(I,L),SHN(I CON16890
       2,L),STFO,VPSHH(I,L),UN(I,L),VNRE(I,L),ENHI,ENHO,SDDO)             CON16900
C                                                                          CON16910
C       CHECK TO SEE IF THE FIRST ROW IN THE SECTOR HAS STEAM SATURATION   CON16920
C       HAS DROPPED BELOW PTLIM. IF IT HAS THEN CHECK2<0 AND I=1.          CON16930
C       DUMMY VALUES MUST THEN BE PLACED IN THOSE VARIABLES NORMALLY       CON16940
C       RETURNED BY HETTRN SINCE HETTRN HAS BEEN BYPASSED.                 CON16950
C                                                                          CON16960
120     IF ((CHECK2.GE.0.).OR.(I.NE.1)) GO TO 130                          CON16970
C                                                                          CON16980
C       SINCE THE SATURATION STEAM PRESSURE IS BELOW PTLIM THEN THE STEAM  CON16990
C       TEMPERATURE IS BELOW COOLANT INLET TEMPERATURE. THIS MEANS NO      CON17000
C       HEAT IS REMOVED FROM THE STEAM AND THE ALMTD IS 0. THE COOLANT     CON17010
C       OUTLET TEMP IS THE SAME AS THE COOLANT INLET TEMP AND THE TUBE     CON17020
C       FILM TEMP IS THE SAME AS COOLANT INLET TEMPS. THE REMAINING        CON17030
C       VARIABLE VALUES ARE APPROXIMATED.                                  CON17040
C                                                                          CON17050
        ALMTD(1,J)=0.                                                      CON17060
        HOMCI=0.                                                           CON17070
        HOMCO=0.                                                           CON17080
        VPSHH(1,J)=STBI                                                    CON17090
        HEFF(1,J)=1.E+8                                                    CON17100
        RC(1,J)=.161E-3                                                    CON17110
        VNRE(1,J)=.9E+5                                                    CON17120
        SHI(1,J)=.136E+4                                                   CON17130
        SHN(1,J)=.136E+5                                                   CON17140
        UN(1,J)=655.                                                       CON17150
        ROUT(1,J)=.136E+5                                                  CON17160
        STFO=STBI                                                          CON17170
        GO TO 150                                                          CON17180
C                                                                          CON17190
C       CHECK TO SEE IF A ROW OTHER THAN THE FIRST ONE IN THE SECTOR HAS   CON17200
C       HAD STEAM SATURATION DROP BELOW PTLIM. IF IT HAS THEN CHECK2<0.    CON17210
C       DUMMY VALUES MUST THEN BE PLACED IN THOSE VARIABLES NORMALLY       CON17220
C       RETURNED BY HETTRN SINCE HETTRN HAS BEEN BYPASSED.                 CON17230
C                                                                          CON17240
130     IF (CHECK2.LT.0) GO TO 140                                         CON17250
        ENHFSV=ENHF                                                        CON17260
        GO TO 150                                                          CON17270
C                                                                          CON17280
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C       IF CHECK2 ≤ 0, THAT INDICATES THAT THE SATURATION STEAM PRESSURE   CON17290
C       IS BELOW PTLIM AND THUS THE STEAM TEMPERATURE IS BELOW COOLANT     CON17300
C       INLET TEMPERATURE. THIS MEANS THAT NO HEAT IS REMOVED FROM THE     CON17310
C       STEAM AND THE ALMTD IS 0. THE COOLANT OUTLET TEMP EQUALS THE       CON17320
C       COOLANT INLET TEMP AND THE TUBE FILM TEMP IS THE SAME AS THE       CON17330
C       COOLANT INLET TEMP. THE REMAINING VARIABLES ARE GIVEN THE LAST     CON17340
C       GOOD VALUES RETURNED BY HETTRN.                                    CON17350
C                                                                          CON17360
140     ALMTD(I,J)=0.                                                      CON17370
        HOMCI=0.                                                           CON17380
        HOMCO=0.                                                           CON17390
        VPSHH(I,J)=STBI                                                    CON17400
        HEFF(I,J)=HEFF(I-1,J)                                              CON17410
        RC(I,J)=RC(I-1,J)                                                  CON17420
        VNRE(I,J)=VNRE(I-1,J)                                              CON17430
        SHI(I,J)=SHI(I-1,J)                                                CON17440
        SHN(I,J)=SHN(I-1,J)                                                CON17450
        UN(I,J)=UN(I-1,J)                                                  CON17460
        ROUT(I,J)=ROUT(I-1,J)                                              CON17470
        STFO=STBI                                                          CON17480
        ENHF=ENHFSV                                                        CON17490
C                                                                          CON17500
150     TB2=VPSHH(I,L)                                                     CON17510
        HFG=HFGFN(STSAT(I,J))                                              CON17520
C                                                                          CON17530
C       CHECK TO SEE IF STEAM FLOW IN A SECTOR HAS ALREADY GONE TO 0       CON17540
C       IF IT HAS CHECK1<0 AND DUMMY VALUES HAVE ALREADY BEEN ASSIGNED     CON17550
C       TO WCNC.                                                           CON17560
C                                                                          CON17570
        IF (CHECK1.LT.0.) GO TO 160                                        CON17580
C                                                                          CON17590
        WCND(I,J)=UN(I,J)*AO*ALMTD(I,J)/HFG*TBNPR(I)                       CON17600
C                                                                          CON17610
C       CHECK TO SEE IF SATURATION PRESSURE HAS ALREADY GONE BELOW PTLIM    CON17620
C       AND DUMMY VARIABLES HAVE BEEN ASSIGNED TO DELPTP                   CON17630
C                                                                          CON17640
C       IF (CHECK2.LT.0) GO TO 170                                         CON17650
C                                                                          CON17660
160     CALL PRSDRP (TAL,VMIX,WS(I,J),WNC,AXO,OD,VPSH,DELPTP,ENHF)         CON17670
C170    CONTINUE                                                           CON17680
        JX=0                                                               CON17690
C$--------------                                                          CON17700
C  SEC A5                                                                  CON17710
C                       TEMP OUTPUT SECTION                                CON17720
C                                                                          CON17730
C  ZZZSEC-A5                                                               CON17740
C---------------                                                           CON17750
        SECA5=0.                                                           CON17760
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      IF (SECA5.NE.1.) GO TO 170                                          CON17770
      WRITE (6,860) I,J                                                   CON17780
      WRITE (6,910) TB2,UN(I,L),VNRE(I,L)                                 CON17790
      WRITE (6,870) ALMTD(I,L),HEFF(I,L)                                  CON17800
      WRITE (6,880) HOMCI,HOMCO                                           CON17810
      WRITE (6,890) RC(I,L),ROUT(I,L)                                     CON17820
      WRITE (6,900) SHI(I,L),SHN(I,L)                                     CON17830
      WRITE (6,920) WNC,WS(I,L)                                           CON17840
      WRITE (6,930) DELPTP,VPSH                                           CON17850
      WRITE (6,940) WCND(I,J),HFG                                         CON17860
      WRITE (6,950) AO,TBNPR(I)                                           CON17870
C$---------------                                                         CON17880
C SEC 6                                                                   CON17890
C                    TEST FOR POSITIVE STM FLOW AND SAT PRESS             CON17900
C                                                                         CON17910
C        WS = STM FLOW TO ONE ROW IN A SECTOR  LB/HR                      CON17920
C        WNCD = CONDENSATE FROM ONE ROW OF TUBES IN A SECTOR  LB/HR       CON17930
C        WNC = N/C GAS FLOW TO ONE ROW OF TUBES IN ASECTOR  LB/HR         CON17940
C        AXO = AREA OPEN TO FLOW IN A ROW OF A SECTOR                     CON17950
C        GFLW = MASS FLW RATE OF MIXTURE IN A TUBE BUNDLE LB/(HR-FT**2)   CON17960
C        I = ROW NUMBER                                                   CON17970
C        AMOLS = MOLES OF STEAM IN A ROW OF A SECTOR                      CON17980
C        PMIX = PRESS OF STM - N/C MIXTURE                                CON17990
C        DELPTP = PRESS DROP ACROSS A ROW OF TUBES                        CON18000
C        AMWNC = MOLECULAR WEIGHT OF N/C                                  CON18010
C        PSAT = SATURATED STEAM PRESS                                     CON18020
C        J = SECTOR NUMBER                                                CON18030
C        STSAT = SATURATED STEAM TEMP - F                                 CON18040
C        TSAT = SATURATED STEAM TEMP - R                                  CON18050
C        PAL = DUMMY FOR PSAT                                             CON18060
C        CHECK1 = INDICATOR THAT NEG. STEAM FLOW HAS BEEN ENCOUNTERED     CON18070
C                 IN SECTOR ANALYSIS                                      CON18080
C        CHECK2 = INDICATOR THAT PRESS<PSATFN(STBI) HAS BEEN              CON18090
C                 ENCOUNTERED IN SECTOR ANALYSIS                          CON18100
C        PTEST = NEXT ROW PRESSURE VALUE TO CHECK FOR A BAD VALUE         CON18110
C        WTEST = NEXT ROW STEAM FLOW TO CHECK FOR A NEGATIVE VALUE        CON18120
C        WTST = TEST VARIABLE WHICH IS NEGATIVE WHEN NEGATIVE STEAM FLOW  CON18130
C               IS ENCOUNTERED IN A SECTOR                                CON18140
C        PTST = TEST VARIABLE WHICH IS A NEGATIVE WHEN PSAT DROPS BELOW   CON18150
C               PTLIM IN A SECTOR                                         CON18160
C                                                                         CON18170
C ZZZ SEC-6                                                               CON18180
C---------------                                                          CON18190
C     CHECK TO SEE IF STEAM FLOW HAS ALREADY GONE TO 0 IN AN EARLIER      CON18200
C     ROW CALCULATIO AND FIXUP HAS BEEN MADE TO WS AND WCND               CON18210
C                                                                         CON18220
170   IF (CHECK1.LT.0) GO TO 180                                          CON18230
      WS(I+1,J)=WS(I,J)-WCND(I,J)                                         CON18240
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C                                                                       CON18250
C       CHECK TO SEE IF STEAM FLOW OF NEXT ROW IS 0 AND DUMMY VALUES    CON18260
C       MUST BE ASSIGNED TO WS AND WCND TO ALLOW THE PROGRAM TO CONTINUE CON18270
C                                                                       CON18280
        IF (WS(I+1,J).LE.1.) IIII=1                                     CON18290
        IF (WS(I,J).LE.1.) GO TO 300                                    CON18300
C                                                                       CON18310
C       BEGIN COMPUTING NEXT ROW PRESSURES                              CON18320
C                                                                       CON18330
180     AMOLS=WS(I+1,J)/18.015                                          CON18340
        SECA6=0.                                                        CON18350
        IIII=0                                                          CON18360
C                                                                       CON18370
C       CHECK TO SEE IF SATURATION PRESSURES HAVE ALREADY GONE BELOW    CON18380
C       PTLIM AND STANDARD FIXUP TO PSAT HAS BEEN MADE. PRESSURE FALLING CON18390
C       BELOW PTLIM IS CONSIDERED ONLY FOR THE CASE OF EXCESSIVE PRESSURE CON18400
C       LOSSES ONLY AND NOT AS A CONSEQUENCE OF LOSS OF STEAM FLOW      CON18410
C                                                                       CON18420
        IF (CHECK2.GE.0) GO TO 190                                      CON18430
        PAL=PSAT(I+1,J)                                                 CON18440
        IF (I.EQ.1) DELPTP=DELPP/(AMOLS/(AMOLS+WNC/AMWNC))              CON18450
        PMIX(I+1,J)=PMIX(I,J)-DELPTP                                    CON18460
        IF (PMIX(I+1,J).LE..001) PMIX(I+1,J)=.001                       CON18470
        GO TO 230                                                       CON18480
C                                                                       CON18490
190     PMIX(I+1,J)=PMIX(I,J)-DELPTP                                    CON18500
        PSAT(I+1,J)=PMIX(I+1,J)*AMOLS/(AMOLS+WNC/AMWNC)                 CON18510
        PAL=PSAT(I+1,J)                                                 CON18520
        PTEST=PSAT(I+1,J)                                               CON18530
        IF (SECA6.NE.1) GO TO 200                                       CON18540
        IF (SECA6.EQ.1) WRITE (6,1020) I,J                              CON18550
        IF (SECA6.EQ.1) WRITE (6,970) WS(I,J),WS(I+1,J)                 CON18560
        IF (SECA6.EQ.1) WRITE (6,1000) PSAT(I,J),PSAT(I+1,J)            CON18570
C                                                                       CON18580
C       CHECK FOR NEXT ROW SATURATION PRESSURE TO SEE IF DROPS BELOW PTLIMCON18590
C                                                                       CON18600
200     IF (PTEST-PTLIM) 210,210,230                                    CON18610
C                                                                       CON18620
C        PSAT(I+1) < PTLIM AND SUBSEQUENT ROW PRESSURES MUST BE FIXED   CON18630
C        UP WITH DUMMY VALUES IN ORDER TO KEEP THE PROGRAM RUNNING.     CON18640
C        PSAT, AND DELPP ARE GIVEN DUMMY VALUES.                        CON18650
C                                                                       CON18660
210     IK2=I+1                                                         CON18670
        SECA6=0.                                                        CON18680
        NRWSP2=NOROWS+1                                                 CON18690
        ROTOG=FLOAT(NRWSP2-I)                                           CON18700
        DELPP=PTLIM/(ROTOG+1)                                           CON18710
C                                                                       CON18720
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C       DELPP IS AN ARBITRARY INCREMENTAL PRESS. DROP OVER REMAINING ROWS  CON18730
C                                                                          CON18740
        DO 220 IK=IK2,NRWSP2                                               CON18750
        PSAT(IK,J)=PSAT(IK-1,J)-DELPP                                      CON18760
220     CONTINUE                                                           CON18770
        X1=PTEST-PTLIM                                                     CON18780
        X2=PSAT(I,J)                                                       CON18790
C                                                                          CON18800
CC       CALCULATE PTST WHICH IS A TEST VALUE INDICATING THAT SATURATION   CON18810
CC       PRESSURES WERE REACHED IN THE ANALYSIS FROM WHICH THE             CON18820
CC       CORRESPONDING TSAT IS EXCEEDED BY THE INLET COOLANT TEMP(IE PTLIM CON18830
CC       WAS VIOLATED) A LARGE NEGATIVE VALUE FOR PTST INDICATES A BAD     CON18840
CC       CONDENSOR DESIGN IN WHICH PTLIM WAS VIOLATED EARLY IN THE SECTOR  CON18850
CC       ANALYSIS. AS THE CONDENSOR MODEL IMPROVES AND SATURATION PRESSURE CON18860
CC       STAYS ABOVE PTLIM THEN PTST CONVERGES TO 0.                       CON18870
C                                                                          CON18880
        PTST(J)=(X1/(X2-X1))-FLOAT(NOROWS-I)                               CON18890
        CHECK2=-2.                                                         CON18900
        PAL=PSAT(I+1,J)                                                    CON18910
        PMIX(I+1,J)=PMIX(I,J)-DELPTP                                       CON18920
        IF (PMIX(I+1,J).LE..001) PMIX(I+1,J)=.001                          CON18930
C                                                                          CON18940
        IF (SECA6.EQ.1) WRITE (6,990) I,J                                  CON18950
        IF (SECA6.EQ.1) WRITE (6,1000) PSAT(I,J),PSAT(I+1,J)               CON18960
        IF (SECA6.EQ.1) WRITE (6,1010) PTST(J)                             CON18970
C                                                                          CON18980
        GO TO 230                                                          CON18990
C$-------------                                                            CON19000
C  SEC 7                                                                   CON19010
CC                    CORRECTION TO CONDENSATE RATE FOR                    CON19020
CC                          SENSIBLE HEAT                                  CON19030
CC                                                                         CON19040
CC          PAL = SAT STM PRESS                                            CON19050
CC          STFO = AVE TEMP OF OUTER TUBE FILM                             CON19060
CC          UN = OVERALL HEAT X-FER COEF FOR A ROW OF TUBES                CON19070
CC          AO = TUBE OUTER SURFACE AREA                                   CON19080
CC          ALMTD = LMTD                                                   CON19090
CC          TBNPR = NUMBER OF TUBES IN A ROW OF A SECTOR                   CON19100
CC          WS = STEAM FLOW TO A ROW OF A SECTOR                           CON19110
CC          WNC = N/C FLOW TO A ROW OF A SECTOR                            CON19120
CC          JGAS = FLAG FOR TYPE OF N/C                                    CON19130
CC          AMWNC = MOLECULAR WEIGHT OF N/C                                CON19140
CC          TAL = SAT STM TEMP ENTERING SECTOR  R                          CON19150
CC          WCNDP = CONDENSATE FROM ONE ROW CORRECTED FOR SENSIBLE         CON19160
CC                    HEAT CHANGE  LB/HR                                   CON19170
CC          WCND = CONDENSATE FROM ONE ROW                                 CON19180
CC          JX =                                                           CON19190
C           IDENT = USER INPUT IDENTIFICALTION STRING FOR RUN              CON19200
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C          AMOLS = MOLES OF STEAM IN A ROW OF A SECTOR                          CON19210
C          PMIX = PRESSURE OF STEAM - N/C MIXTURE                               CON19220
C          PSAT = SATURATED STEAM PRESS                                         CON19230
C          TSAT = SATURATED STEAM TEMP  R                                       CON19240
C          STSAT = SATURATED STEAM TEMP  F                                      CON19250
C                                                                               CON19260
C                                                                               CON19270
C  ZZZ SEC-7                                                                    CON19280
C-----------------                                                              CON19290
230     TSAT=TSATFN(PAL)                                                        CON19300
        SECA7=0.                                                                CON19310
        STSAT(I+1,JJ=TSAT-459.69                                                CON19320
        IF (STSAT(I+1,JJ-STFO) 240,240,250                                      CON19330
240     STSAT(I+1,JJ=STFO                                                       CON19340
        TSAT=STSAT(I+1,JJ+459.69                                                CON19350
250     CONTINUE                                                                CON19360
        WCNDP=(UN(I,JJ*AO*ALMTC(I,J)*TBNPR(I)-(WS(I,J)*CPSFN(TSAT)/18.015+CON19370
       1WNC*CPAFN(TSAT,JGAS)/AMWNC)*(TAL-TSAT))/HFG                             CON19380
        IF (SECA7.EC.1) WRITE (6,1070) WCND(I,J),WCNDP                          CON19390
        IF (SECA7.EQ.1) WRITE (6,1080) TAL,TSAT                                 CON19400
C                                                                               CON19410
CCC                                                                             CON19420
CCC     CHECK TO SEE IF WCND IS 0 WHICH CAN OCCUR IF PSAT HAS DROPPED           CON19430
CCC     BELOW PTLIM (CHECK2<0). IF IT HAS THERE IS NO HEAT TRANSFER FROM        CON19440
CCC     THE STEAM AND NO NEED TO CORRECT FOR SENSIBLE HEAT                      CON19450
C                                                                               CON19460
        IF (CHECK2.LT.0) WCNDP=WCND(I,J)                                        CON19470
C                                                                               CON19480
CCC     CHECK TO SEE IF STEAM FLOW HAS ALREADY GONE TO 0 (CHECK<0)              CON19490
CCC     AND WCND HAS BEEN FIXED UP WITH DUMMY VALUES                            CON19500
C                                                                               CON19510
        IF (CHECK1.LT.0) WCNDP=WCND(I,J)                                        CON19520
C                                                                               CON19530
CCC     IF CONDENSATE FLOW HAS GONE TO 0 AVOID ITERATIONS                       CON19540
C                                                                               CON19550
        IF (WCND(I,JI.EQ.0.) GO TO 290                                          CON19560
C                                                                               CON19570
CCC     IF EITHER CHECK IS TRUE THEN AVOID CORRECTIVE ITERATION TO WCND          CON19580
C                                                                               CON19590
        IF (ABS(WCNDP/WCND(I,J)-1.0)-.005) 290,260,260                          CON19600
260     JX=JX+1                                                                 CON19610
        IF (JX-50) 280,280,270                                                  CON19620
270     IF (SECA7.EQ.1) WRITE (6,1120) IDENT,I,J,I,J                            CON19630
        GO TO 290                                                               CON19640
280     WCND(I,JI=WCNDP                                                         CON19650
        GO TO 170                                                               CON19660
290     CONTINUE                                                                CON19670
        SECA6=0.                                                                CON19680
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C                                                                       CON19690
C       CHECK TO SEE IF STEAM FLOW HAS GONE TO 1 IN AN EARLIER ROW      CON19700
C       CALCULATION AND SUBSEQUENT ROWS HAVE BEEN FIXED UP WITH DUMMY   CON19710
C       VALUES. A NEGATIVE CHECK1 INDICATES FIXUP HAS BEEN MADE FOR     CON19720
C       THAT SECTOR                                                     CON19730
C                                                                       CON19740
        IF (CHECK1.GE.0) GO TO 300                                      CON19750
        GO TO 350                                                       CON19760
C                                                                       CON19770
300     WTEST=WS(I+1,J)                                                 CON19780
C                                                                       CON19790
C       CHECK THE NEXT ROW TO SEE IF STEAM FLOW < 1                     CON19800
C                                                                       CON19810
        IF (WTEST-1.) 310,310,340                                       CON19820
C                                                                       CON19830
C       IF STEAM FLOW HAS GONE TO 1 THEN A STANDARD FIXUP IS MADE TO    CON19840
C       ALLOW THE PROGRAM TO CONTINUE AND DUMMY VALUES FOR STEAM FLOW   CON19850
C       AND CONDENSATE ARE ENTERED INTO THE REMAINING ROWS. IF STEAM FLOW CON19860
C       HAS GONE TO 1 THAT INDICATES ZERO STEAM FLOW. A VERY SMALL NUMBER CON19870
C       WILL BE USED TO SIMULATE 0 STEAM FLOW IN THE REMAINING ROWS.    CON19880
C                                                                       CON19890
310     IK1=I+1                                                         CON19900
        ROTOGO=FLOAT(NOROWS-I)                                          CON19910
        WSEND=(WTEST-1.)/(WS(I,J)-WTEST+1.)                             CON19920
        WTST(J)=WSEND-ROTOGO                                            CON19930
C                                                                       CON19940
        IF (SECA6.EQ.1) WRITE (6,960) I,J                               CON19950
        IF (SECA6.EQ.1) WRITE (6,970) WS(I,J),WTEST                     CON19960
        IF (SECA6.EQ.1) WRITE (6,980) WTST(J)                           CON19970
C                                                                       CON19980
C       CALCULATE NEGATIVE FLOW RATE FOR USE IN CALCULATING EXTITFR     CON19990
C                                                                       CON20000
        DO 320 KK=IK1,NCROWS                                            CON20010
        TUBDRY=TUBDRY+TBNPR(KK)                                         CON20020
320     CONTINUE                                                        CON20030
        TUBDRY=TUBDRY-WSEND*TBNPR(I)                                    CON20040
        CUMDRY=CUMDRY+TUBDRY                                            CON20050
        SUBRAT=WCND(I-1,J)/TBNPR(I)                                     CON20060
        SUBAVE=SUBAVE+SUBRAT                                            CON20070
        NBAD=NBAD+1                                                     CON20080
        SUBFLO=SUBFLO+SUBRAT*TUBDRY                                     CON20090
C                                                                       CON20100
        NRWSP1=NOROWS+1                                                 CON20110
        RSTOGO=FLOAT(NRWSP1-I)                                          CON20120
        WS(I,J)=(1.0)*(RSTOGO+1)                                        CON20130
        WCND(I,J)=WS(I,J)                                               CON20140
        DELWS=WS(I,J)/(RSTOGO+1)                                        CON20150
        DELWC=WCND(I,J)/(RSTOGO+1)                                      CON20160
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      DO 330 IK=IK1,NRWSP1                                                  CON20170
      IF (SECA6.EQ.1) WRITE (6,970) WS(IK,J)                                CON20180
      WS(IK,J)=WS(IK-1,J)-DELWS                                             CON20190
330   WCND(IK,J)=WCND(IK-1,J)-DELWC                                         CON20200
C                                                                           CON20210
CC    CALCULATE A VALUE FOR THE TEST VARIABLE (WTST) INDICATING 0 OR        CON20220
CC    NEGATIVE STEAM FLOW. A LARGE NEGATIVE VALUE FOR WTST INDICATES        CON20230
CC    A VERY BAD CONDENSOR MODEL WHERE NEGATIVE STEAM FLOW WAS              CON20240
CC    ENCOUNTERED EARLY IN THE SECTORS. AS THE CONDENSOR MODEL IMPROVES     CON20250
CC    STEAM FLOW STAYS POSITIVE THROUGHOUT THE CONDENSOR AND WTST           CON20260
CC    CONVERGES TO 0.                                                       CON20270
C                                                                           CON20280
      CHECK1=-2.                                                            CON20290
      IF (IIII.EQ.1) GO TO 180                                              CON20300
      GO TO 350                                                             CON20310
340   WCND(I,J)=WCNDP                                                       CON20320
      WS(I+1,J)=WS(I,J)-WCND(I,J)                                           CON20330
350   GFLW(I,J)=(WS(I,J)+WNC)/AXO                                           CON20340
      AMOLS=WS(I+1,J)/18.015                                                CON20350
C                                                                           CON20360
CC    CHECK TO SEE IF PRESURE HAS ALREDY GONE BELOW PTLIM                   CON20370
CC    AND DUMMY VALUES ARE IN THE PRESSURE ARRAY (CHECK2<0)                 CON20380
C                                                                           CON20390
      IF (CHECK2.LT.0.) GO TO 360                                           CON20400
C                                                                           CON20410
      PSAT(I+1,J)=PMIX(I+1,J)*AMOLS/(AMOLS+WNC/AMWNC)                       CON20420
360   TSAT=TSATFN(PSAT(I+1,J))                                              CON20430
      STSAT(I+1,J)=TSAT-459.69                                              CON20440
C$-------------                                                             CON20450
C  SEC A7                                                                   CON20460
CC                    TEMP OUTPUT SECTION                                   CON20470
CC                                                                          CON20480
C  ZZZ SEC-A7                                                               CON20490
C-------------                                                              CON20500
      IF (SECA7.NE.1.) GO TO 370                                            CON20510
      WRITE (6,1030) I,J                                                    CON20520
      WRITE (6,1040) WS(I,J),WCND(I,J)                                      CON20530
      WRITE (6,1050) TSAT,STSAT(I,J)                                        CON20540
      WRITE (6,1060) GFLW(I,J),PSAT(I,J)                                    CON20550
C$-------------                                                             CON20560
C  SEC 8                                                                    CON20570
CC                    COMPLETION OF MAIN ROW AND SECTOR LOOPS               CON20580
CC                                                                          CON20590
CC             NOTE THAT THE MAIN ROW LOOP IS COMPLETED IN IN LINE 360,     CON20600
CC             AND THE MAIN SECTOR LOOP IS COMPLETED IN LINE 390.           CON20610
CC                                                                          CON20620
CC         VG = SPECIFIC VOLUME OF STM                                      CON20630
C          VMIX = SPECIFIC VOLUME OF STM-N/C MIXTURE                        CON20640
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C          AMOLS = MOLES OF STM TO A ROW                                          CON20650
C          TSAT = STM SATURATION TEMP  R                                          CON20660
C          PMIX = ST -N/C MIXTURE PRESSURE                                        CON20670
C          AMWNC = MOLECULAR WEIGHT OF N/C GASSES                                 CON20680
C          VNC = SPECIFIC VOLUME OF N/C GASSES                                    CON20690
C          WNC = N/C FLOW TO A ROW OF A SECTOR                                    CON20700
C          AMOLSC = MOLES OF A N/C TO A SECTOR                                    CON20710
C          VEL = STM-N/C MIXTURE VELOCITY IN A ROW OF TUBES                       CON20720
C          WS = STM FLOW TO A ROW IN A SECTOR  LB/HR                              CON20730
C          AOTFLW = AREA OPEN TO STM FLOW IN A ROW OF TUBES                       CON20740
C          SMTBI = SUM OF (COOLANT INLET TEMP*COOLANT FLOW RATE)                  CON20750
C          WB = COLLANT FLOW TO ONE TUBE IN THE CONDENSER                         CON20760
C          STBI = COOLANT INLET TEMP                                              CON20770
C          TBNPR = NUMBER OF TUBES IN A ROW OF A SECTOR                           CON20780
C          SMWB = ROW BY ROW SUM OF COOLANT FLOW                                  CON20790
C          SMTB2 = ROW BY ROW SUM OF (COOLANT OUTLET TEMP*FLOW RATE)              CON20800
C          TB2 = COOLANT OUTLET TEMP FOR A TUBE                                   CON20810
C          SUMQ = SUM OF HEAT DUTY ON ROWS OF TUBES                               CON20820
C          UN = OVERALL HEAT X-FER COEF FOR A ROW                                 CON20830
C          AO = TUBE OUTER SURFACE AREA                                           CON20840
C          ALMTC = LMTD                                                           CON20850
C          QOA = HEAT FLUX ACROSS TUBE WALL                                       CON20860
C          CUMDP = ACCUMULATED PRESS DROP FROM INLET TO CURRENT ROW               CON20870
C          PMIX = PRESS OF STM-N/C MIXTURE                                        CON20880
C          PHP = OVERALL POWER TO DRIVE THE COOLANT THROUGH THE CONDENSER         CON20890
C                AND THE COOLER TUBES IN HP.                                      CON20900
C          DELP = PRESSURE DROP ACROSS A SECTOR                                   CON20910
C          DELPTP = PRESSURE DROP ACROSS A ROW                                    CON20920
C          TAL = SAT STEAM TEMP  R                                                CON20930
C          I = ROW NUMBER                                                         CON20940
C          IT = DUMMY LOOP VARIABLE(IT = I)                                       CON20950
C          SVMIX1 = SPECIFIC VOLUME OF STM-N/C MIXTURE ENTERING CONDENSER         CON20960
C          WGAS = FLOW OF N/C GAS TO A SECTOR                                     CON20970
C          AOTFLW = AREA OPEN TO STEAM FLOW IN A ROW OF TUBES                     CON20980
C          C = USED TO ADJUST STEAM FLOW TO MATCH PRESS DROPS IN SEC-10           CON20990
C  ZZZ SEC-8                                                                      CON21000
C--------------                                                                   CON21010
370     VG=VGFN(TSAT,PMIX(I+1,J))                                                 CON21020
        AMOLSC=WNC/AMWNC                                                          CON21030
        VNC=(10.729*TSAT)/(AMWNC*PMIX(I+1,J))                                     CON21040
        VMIX=1.0/((AMOLS/(VG*(AMOLS+AMOLSC)))+(AMOLSC/(VNC*(AMOLS+AMOLSC))       CON21050
       1))                                                                        CON21060
C       IF (I.EQ.NOROWS) GOTO 190                                                 CON21070
        VEL(I+1,J)=(WS(I+1,J)+WNC)/(AOTFLW(I+1))*VMIX/3600.0                      CON21080
        SMTBI=SMTBI+WB*STBI*TBNPR(I)                                              CON21090
        SMWB=SMWB+WB*TBNPR(I)                                                     CON21100
        SMTB2=SMTB2+WB*TBNPR(I)*TB2                                               CON21110
        SUMQ=SUMQ+UN(I,J)*AO*ALMTD(I,J)*TBNPR(I)                                  CON21120
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      QQA(I,J)=UN(I,J)*ALMTD(I,J)                                          CON21130
      CUMDP(I,J)=(PMIX(1)-PMIX(I+1,J)                                      CON21140
      DELP(J)=DELP(J)+DELPTP                                               CON21150
      TAL=TSAT                                                             CON21160
380   CONTINUE                                                             CON21170
      C(J)=(WS(1,J)+WGAS(J))/SQRT(DELP(J))                                 CON21180
C                                                                          CON21190
C     INCLUDE ONLY THOSE SECTORS WHERE STEAM FLOW HAS NOT GONE TO 0        CON21200
C     IN STMSUM SO AS NOT TO INCLUDE DUMMY VALUES IN THE CALCULATION       CON21210
C     OF EXIT STEAM FRACTION                                               CON21220
C                                                                          CON21230
      IF (CHECK1.GE.0) STMSUM=STMSUM+WS(NOROWS+1,J)                        CON21240
390   CONTINUE                                                             CON21250
C$-------------                                                            CON21260
C  SEC A8                                                                  CON21270
C                        TEMP OUTPUT SECTION                               CON21280
C ZZZ SEC-A8                                                               CON21290
C-------------                                                             CON21300
      SECA8=0.                                                             CON21310
      IF (SECA8.NE.1.) GO TO 410                                           CON21320
      WRITE (6,1090)                                                       CON21330
      DO 400 I=1,ISEC                                                      CON21340
400   WRITE (6,1100) WTST(I),PTST(I)                                       CON21350
410   CONTINUE                                                             CON21360
C$-------------                                                            CON21370
C  SEC 9                                                                   CON21380
C                        EXIT FRACTION AND PRESS ADJUST                    CON21390
C ZZZ SEC-9                                                                CON21400
C-------------                                                             CON21410
      PMXEXT=0.                                                            CON21420
      DELPVE=0.                                                            CON21430
      PSUM=0.                                                              CON21440
      VELEXT=0.                                                            CON21450
      DO 420 I=1,ISEC                                                      CON21460
      PAL=PSAT(KSTOP,I)                                                    CON21470
      PSUM=PSUM+PAL/SECFLG                                                 CON21480
      VELEXT=VELEXT+VEL(NOROWS+1,I)                                        CON21490
      DELPVE=DELPVE+DELP(I)                                                CON21500
420   PMXEXT=PMXEXT+PMIX(NOROWS+1,I)                                       CON21510
C                                                                          CON21520
C      MAKE PTST AND EXIT STEAM FRACTION VARIABLES CONTINUOUS              CON21530
C      THIS IS DONE TO SATISFY AND ENHANCE OPTIMIZER CALCULATIONS.         CON21540
C      THE VARIABLE PTST IS GIVEN THE LAST ROW +1 PRESSURE VALUES IF       CON21550
C      IT IS NON-NEGATIVE. IN ORDER TO MAKE EXIT STEAM FRACTION            CON21560
C      (EXITFR) CONTINOUS THE VARIABLE FR IS CREATED WHICH INCORPORATES    CON21570
C      WTST OF ALL THE SECTORS. IF THE WTST VALUES ARE LARGE NEGATIVE      CON21580
C      NUMBERS THEN FR-->-1. AS WTST VALUES APPROACH 0 INDICATING STEAM    CON21590
C      THROUGHOUT THE CONDENSOR THEN FR-->0. FR IS THEN ADDED TO EXITFR    CON21600
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C       TO MAKE IT CONTINOUS FROM 1-->-1 REFLECTING THE CONDENSOR IN      CON21610
C       NO STEAM IS EXTRACTED AND THE CONDENSOR WHERE ALL THE TUBES ARE   CON21620
C       DRY.                                                              CON21630
C                                                                         CON21640
        DO 430 I=1,ISEC                                                   CON21650
        IF (PTST(I).GE.0.) PTST(I)=PSAT(NOROWS+1,1)-PTLIM                 CON21660
430     WTSAV=WTSAV+WTST(I)                                               CON21670
        FR=-(SUBFLO)/WSI                                                  CON21680
        DELPVE=DELPVE/SECFLG                                              CON21690
        DO 450 J=1,ISEC                                                   CON21700
C                                                                         CON21710
        IF (ABS(DELP(J)/DELPVE-1.0)-.01) 450,450,440                      CON21720
440     IF (ABS(DELPVE).GT.0.001) GO TO 460                               CON21730
450     CONTINUE                                                          CON21740
        GO TO 580                                                         CON21750
460     CONTINUE                                                          CON21760
        DLPVES=DELPVE                                                     CON21770
        CONSM=0.0                                                         CON21780
        WNCFR=WNCI/(WNCI+WSI)                                             CON21790
        DO 470 J=1,ISEC                                                   CON21800
        CONSM=CONSM+C(J)                                                  CON21810
470     CONTINUE                                                          CON21820
        DELPVE=(WSAVE*SECFLG)**2/CONSM**2                                 CON21830
        DELPVE=(DELPVE+DLPVES)/2.0                                        CON21840
        DMAX=ABS(DELPVE-DELP(1))                                          CON21850
        JMAX=1                                                            CON21860
        DO 480 J=2,ISEC                                                   CON21870
        DHOLD=ABS(DELPVE-DELP(J))                                         CON21880
        IF (DHOLD.LE.DMAX) GO TO 480                                      CON21890
        DMAX=DHOLD                                                        CON21900
        JMAX=J                                                            CON21910
480     CONTINUE                                                          CON21920
        WSPT=0.0                                                          CON21930
        WPT=0.0                                                           CON21940
        DO 500 J=1,ISEC                                                   CON21950
        WP(J)=C(J)*SQRT(DELPVE)                                           CON21960
        WSP(J)=WP(J)*WSI/(WNCI+WSI)                                       CON21970
        IF (J.EQ.JMAX) GO TO 500                                          CON21980
        FAC=WSP(J)-WS(1,J)                                                CON21990
        AFAC=ABS(FAC)                                                     CON22000
        IF (AFAC.LT.1.E-3) GO TO 490                                      CON22010
        CHGSC=0.5*WS(1,J)**0.26                                           CON22020
        IF (IPLOOP.GT.3) CHGSC=CHGSC/IPLOOP*2.0                           CON22030
        WSP(J)=WS(1,J)+FAC/AFAC*SQRT(AFAC)*CHGSC                          CON22040
490     CONTINUE                                                          CON22050
        WSPT=WSPT+WSP(J)                                                  CON22060
        WGAS(J)=WSP(J)*WNCFR                                              CON22070
        WP(J)=WSP(J)+WGAS(J)                                              CON22080
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      WPT=WPT+WP(J)                                                     CON22090
500   CONTINUE                                                          CON22100
      WSP(JMAX)=WSI-WSPT                                                CON22110
      WSPT=WSPT+WSP(JMAX)                                               CON22120
      WGAS(JMAX)=WSP(JMAX)*WNCFR                                        CON22130
      WP(JMAX)=WSP(JMAX)+WGAS(JMAX)                                     CON22140
      WPT=WPT+WP(JMAX)                                                  CON22150
      IPLOOP=IPLOCP+1                                                   CON22160
C                                                                       CON22170
C     CHECK FOR STEAMM ADJUSTMENTS WHICH TRY TO PUT TO LOW A STEAM      CON22180
C     VALUE INTO A SECTOR                                               CON22190
C                                                                       CON22200
510   IFAIL=0                                                           CON22210
      DO 520 K=1,ISEC                                                   CON22220
      COMP=WSI/200.                                                     CON22230
      IF (WSP(K).LT.COMP) IFAIL=K                                       CON22240
      IF (WSP(K).LT.COMP) WRITE (6,999)                                 CON22250
999   FORMAT (1X,'STEAM FLOW ADJUSTMENT WAS REQUIRED')                  CON22260
      IF (WSP(K).LT.COMP) GO TO 530                                     CON22270
520   CONTINUE                                                          CON22280
      GO TO 550                                                         CON22290
530   DIFF=2.*COMP-WSP(IFAIL)                                           CON22300
      WSP(IFAIL)=2.*COMP                                                CON22310
      ADJ=DIFF/FLOAT(ISEC-1)                                            CON22320
      DO 540 J=1,ISEC                                                   CON22330
      IF (J.EQ.IFAIL) GO TO 540                                         CON22340
      WSP(J)=WSP(J)-ADJ                                                 CON22350
540   CONTINUE                                                          CON22360
      GO TO 510                                                         CON22370
550   CONTINUE                                                          CON22380
C                                                                       CON22390
      DO 560 J=1,ISEC                                                   CON22400
560   WS(1,J)=WSP(J)                                                    CON22410
      IF (IPLOOP-50) 20,20,570                                          CON22420
570   WRITE (6,1110) IDENT                                              CON22430
C                                                                       CON22440
C     INCORPORATE FR INTO EXITFR TO MAKE IT CONTINUOUS FROM 1-->-1      CON22450
C                                                                       CON22460
580   EXITFR=STMSUM/WSI+FR                                              CON22470
      WSEXIT=STMSUM                                                     CON22480
      VELEXT=VELEXT/SECFLG                                              CON22490
C     DELPVE = DELPVE/SECFLG                                            CON22500
      PMXEXT=PMXEXT/SECFLG                                              CON22510
      TSATEX=TSATFN(PSUM)                                               CON22520
      AMLSEX=STMSUM/18.015                                              CON22530
      IF ((STMSUM.LE.0.).AND.(PRCCLR.GT.0.)) AMLSEX=1.0/18.015          CON22540
      EXITFC=1.                                                         CON22550
      IF (PRCCLR.EQ.0.0) EXITOA=EXITFR                                  CON22560
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      IF (PRCCLR.EQ.0.0) GO TO 590                                          CON22570
C                                                                           CON22580
CC    CALL TO COOLER, IF THERE IS ONE                                       CON22590
C                                                                           CON22600
      ENHIC=ENHI                                                            CON22610
      ENHOC=ENHO                                                            CON22620
      ENHFC=ENHF                                                            CON22630
      SHWINC=SHWINV                                                         CON22640
      TB2C=TB2                                                              CON22650
      WBC=WB                                                                CON22660
      IF (NBAD.GT.0) WCNDAV=SUBAVE/FLOAT(NBAD)                              CON22670
      CALL COOLEX (TBDRYC,WCNDAV,SBFLOC,WSOUT)                              CON22680
C                                                                           CON22690
CC    CALCULATE OVERALL POWER REQUIRE TO DRIVE THE COOLANT                  CON22700
C                                                                           CON22710
      PHP=PHP*(SMWBC/(SMWBC+SMWB)+1.)                                       CON22720
C                                                                           CON22730
C     CALCULATE THE OVERALL COOLER/CONDENSER VOLUME                         CON22740
      VOL1=(VOL1+VOLC)                                                      CON22750
C                                                                           CON22760
CC    CALCULATE OVERALL EXIT FRACTION                                       CON22770
C                                                                           CON22780
      IF ((EXITFR.GT.0.).AND.(EXITFC.GT.0.)) EXITOA=EXITFR*EXITFC           CON22790
      IF ((EXITFR.GT.0.).AND.(EXITFC.GT.0.)) RETURN                         CON22800
C                                                                           CON22810
      EXITOA=WSOUT/WSI+(-(SUBFLO+SBFLOC)/WSI)                               CON22820
C                                                                           CON22830
590   RETURN                                                                CON22840
600   FORMAT (1X,7HSECTOR ,I3,2X,5HROW  ,I4)                                CON22850
610   FORMAT (1H1,37H     *****   OUTPUT FOR SEC-2   *****)                 CON22860
620   FORMAT (1H0,10HWSI        ,10HWNCI       )                            CON22870
630   FORMAT (1H0,10HWS(1,I)    ,10HWGAS(I)    )                            CON22880
640   FORMAT (1H0,10HHFG        ,10HAOTFLW(I)  )                            CON22890
650   FORMAT (1H0,10HTSAT1      ,10HSTSAT1     )                            CON22900
660   FORMAT (1H0,10HPSAT1      ,10HPMIX1      )                            CON22910
670   FORMAT (1H0,10HAMOLNC     ,10HAMOLSS     ,10HAMOLST     )             CON22920
680   FORMAT (1H0,10HSVNC1      ,10HSVMIX1     )                            CON22930
690   FORMAT (1H0,10HVG1        ,10HG2         )                            CON22940
700   FORMAT (1H ,2F10.3)                                                   CON22950
710   FORMAT (1H ,3F10.3)                                                   CON22960
720   FORMAT (1H0,10HSECFAR     ,10HARAT       )                            CON22970
730   FORMAT (1H0,10HVEL1       ,5HVEL2 )                                   CON22980
740   FORMAT (1H0,10HDELP1      ,5HDELP2)                                   CON22990
750   FORMAT (1H ,2F10.4)                                                   CON23000
760   FORMAT (1H1,29HOUTPUT FOR SEC-3 -SECTOR NO. ,I2)                      CON23010
770   FORMAT (1H0,36HENTERING PRESSURES IN PSI - MIXTURE=,E10.3,13H SATU    CON23020
     1RATION= ,E10.3)                                                       CON23030
780   FORMAT (1H ,21HENTERING STM TEMPS - ,F6.2,4H F  ,F6.2,2H R)           CON23040
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790   FORMAT (1H ,32HENT SP. VOL. IN FT**3/LBM - STM=,E10.3,9H N/C GAS=,CON23050
     1E10.3,9H MIXTURE=,E10.3)                                          CON23060
800   FORMAT (1H ,23HENTERING STM VELOCITY =,E10.3,8H  FT/SEC)           CON23070
810   FORMAT (1HO,33H** OUTPUT FOR SEC-4 - ROW NUMBER ,I4)               CON23080
820   FORMAT (1HO,33HTUBE WALL AREA - SQ.FT. - INSIDE=,E10.3,10H  OUTSIDCON23090
     1E=,E10.3)                                                         CON23100
830   FORMAT (1H ,9HTUBE ID= ,F6.3,30H FT - TUBE X-SECTIONAL AREA =,E10CON23110
     1.3,6H FT**2)                                                      CON23120
840   FORMAT (1H ,24HLOG MEAN TUBE THICKNESS=,E10.3,25H FT - LOG MEAN TUCON23130
     1BE AREA=,E10.3,6H FT**2)                                          CON23140
850   FORMAT (1H ,30HINVERSE WALL HEAT X-FER COEF =,E10.3,17H HR-FT**2-FCON23150
     1/BTU)                                                             CON23160
860   FORMAT (1HO,22HIN SECALC, SEC-5, ROW=,I4,9H, SECTOR=,I3)           CON23170
870   FORMAT (1H ,7HALMTD =,E10.3,8H HEFF  =,E10.3)                      CON23180
880   FORMAT (1H ,7HHOMCI =,E10.3,8H HOMCO =,E10.3)                      CON23190
890   FORMAT (1H ,7HRC    =,E10.3,8H ROUT  =,E10.3)                      CON23200
900   FORMAT (1H ,7HSHI   =,E10.3,8H SHN   =,E10.3)                      CON23210
910   FORMAT (1H ,7HTB2   =,E10.3,8H UN    =,E10.3,8H VNRE  =,E10.3)     CON23220
920   FORMAT (1H ,7HWNC   =,E10.3,8H WS    =,E10.3)                      CON23230
930   FORMAT (1H ,7HDELPTP=,E10.3,8H VPSH  =,E10.3)                      CON23240
940   FORMAT (1H ,7HWCND  =,E10.3,8H HFG   =,E10.3)                      CON23250
950   FORMAT (1H ,7HAO    =,E10.3,8H TBNPR =,E10.3)                      CON23260
960   FORMAT (1HO,32HNEG STEAM MASS FLOW IN SEC-6 ROW,I4,10H OF SECTOR,ICON23270
     14)                                                                CON23280
970   FORMAT (1H ,18HCURRENT FLOW RATE=,F12.6,17H  NEXT FLOW RATE=,F12.6CON23290
     1)                                                                 CON23300
980   FORMAT (1H ,8HWTST(I)=,F12.6)                                      CON23310
990   FORMAT (1HO,30HNEGATIVE SAT PRSS IN SEC-6 ROW,I4,9H  SECTOR ,I4)   CON23320
1000  FORMAT (1H ,18HCURRENT SAT PRESS=,E10.3,11H  NEXT ROW=,E10.3)      CON23330
1010  FORMAT (1H ,8HPTST(I)=,E10.3)                                      CON23340
1020  FORMAT (1H ,25HNO PROBLEMS IN SE-6, ROW=,I4,8H SECTOR=,I4)         CON23350
1030  FORMAT (1HO,23HOUTPUT FROM SEC-7, ROW ,I4,11H OF SECTOR ,I4)       CON23360
1040  FORMAT (1H ,9HWS(I,J) =,E10.3,13H  WCND(I,J) =,E10.3)              CON23370
1050  FORMAT (1H ,6HTSAT =,E10.3,14H  STSAT(I,J) =,E10.3)                CON23380
1060  FORMAT (1H ,11HGFLW(I,J) =,E10.3,13H  PSAT(I,J) =,E10.3)           CON23390
1070  FORMAT (1H ,28HSEC-7, BELOW 130, WCND(I,J)=,E10.3,8H  WCNDP=,E10.3CON23400
     1)                                                                 CON23410
1080  FORMAT (1H ,22HSEC-7, BELOW 130, TAL=,E10.3,6H TSAT=,E10.3)        CON23420
1090  FORMAT (1H1,3X,4HWTST,8X,4HPTST/)                                  CON23430
1100  FORMAT (1H ,E10.3,2X,E10.3,2X,E10.3)                               CON23440
1110  FORMAT (1H1,19A4,A3,40HNO CONVERGENCE IN COND. DELTA P (IPLOOP))   CON23450
1120  FORMAT (1H1,19A4,A3/1HO,5X,2HI=,I2,5X,2HJ=,I1/1HO,24HNO CONVERGENC CON23460
     1E FOR WCND(,I2,1H,,I1,1H))                                        CON23470
      END                                                               CON23480
C                                                                       CON23490
C*********************************************************************  CON23500
C*********************************************************************  CON23510
C                                                                       CON23520
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      SUBROUTINE HETTRN (ALST,AXO,IR,LJ,OD,WB,SHWINV,STSAT,TID,WNC,WST,ACON23530
     1LMTD,ENHF,HEFF,HOMCI,HOMCO,RC,ROUT,SHI,SHNF,STFO,TB2,VNF,XNRE,ENHICON23540
     2,ENHO,SDD)                                                        CON23550
C-----------------                                                      CON23560
C  HET 1                                                               CON23570
C                       SUBROUTINE HETTRN                              CON23580
C                                                                      CON23590
C          HETTRN CALLED BY: SECALC                                    CON23600
C          SUBROUTINES CALLED BY HETTRN:                               CON23610
C               , DSFVTY ,                                             CON23620
C          FUNCTION ROUTINES CALLED BY HETTRN:                         CON23630
C               , PSATFN , SMUFN , AMUFN , HFCFN , SKBFN ,             CON23640
C               , BMUFN , CPFN , RDEFN ,                               CON23650
C                                                                      CON23660
C-----------------                                                     CON23670
C**    DEC 69 REV.    COLBJ,FDAVE                                      CON23680
       COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON23690
     1TSATI,TUBESW,NCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON23700
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON23710
     3,WSI,PFILL                                                       CON23720
       COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)                        CON23730
       COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST                       CON23740
       DIMENSION R2(3),E2OK(3)                                         CON23750
       HETON=0.                                                        CON23760
       IF (HETCN.NE.1.) GO TO 10                                       CON23770
       M5=1                                                            CON23780
       WRITE (6,310) M5                                                CON23790
       WRITE (6,320) IR,LJ                                             CON23800
       WRITE (6,330) OD,TID                                            CON23810
       WRITE (6,340) SHWINV,STSAT                                      CON23820
       WRITE (6,350) WST,WNC                                           CON23830
C$-------------                                                        CON23840
C  HET 2                                                               CON23850
C                       DATA INITIALIZATION:                           CON23860
C                                                                      CON23870
C          BB  = COOLANT FLOW IN TUBE  LBM/HR-FT**2                    CON23880
C       DGFLM =CALCULATED TEMP DROP ACROSS FILM???                     CON23890
C       DLFLM = CALCULATED TEMP DROP ACROSS LIQUID FILM???             CON23900
C       HEFF = NONCONDENSIBLE FILM HEAT TRANSFER COEF, BTU/HR-FT**2-F  CON23910
C       UEST = ESTIMATED OVERALL HEAT TRANSFER COEF                    CON23920
C                                                                      CON23930
C          VALUES FOR USE IN SUBROUTINE DFSVTY                         CON23940
C       E2OK = FORCE CONSTANT FOR NONCOND GAS                          CON23950
C       R2 = GAS COLLISION DIAMETER IN ANGSTROMS                       CON23960
C ZZZ HET-2                                                            CON23970
C-----------------                                                     CON23980
10     IF (WNC.EQ.0.) DGFLM=0.                                         CON23990
       IF ((LJ.EQ.1).AND.(IR.EQ.1)) GO TO 20                           CON24000
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      IF (IR.EQ.1) GO TO 30                                                    CON24010
      UEST=UESTSV                                                              CON24020
      HEFF=HEFFSV                                                              CON24030
      DGFLM=DGFLMS                                                             CON24040
      DLFLM=DLFLMS                                                             CON24050
      TB2=TB2SV                                                                CON24060
      XNRET=XNRES                                                              CON24070
      GO TO 40                                                                 CON24080
20    IF (IFIRST.EQ.0) GO TO 30                                                CON24090
      HEFF=2100.                                                               CON24100
      DATA UEST,DGFLM,DLFLM,XNRET/700.,0.05,2.0,100000./                       CON24110
      DATA R2,E20K/3.617,3.996,3.838,97.0,190.0,140.75/                        CON24120
      TB2=STB2ES                                                               CON24130
      IFIRST=0                                                                 CON24140
      GO TO 40                                                                 CON24150
30    UEST=UEST1                                                               CON24160
      HEFF=HEFF1                                                               CON24170
      DGFLM=DGFLM1                                                             CON24180
      DLFLM=DLFLM1                                                             CON24190
      TB2=TB21                                                                 CON24200
      XNRET=XNRE1                                                              CON24210
40    CONTINUE                                                                 CON24220
C                                                                              CON24230
C                                                                              CON24240
C     FDAVE IS AN INPUT ITEM WITH A VALUE BETWEEN 0 AND 1 RELATED TO TUBE      CON24250
C     SPACING AND ORIENTATION.                                                 CON24260
      FDAVE=0.5                                                                CON24270
C                                                                              CON24280
C                                                                              CON24290
      BNF=ANT(IR,LJ)                                                           CON24300
      IF (BNF.LT.1.) BNF=1.                                                    CON24310
      BB=WB/(PI*TID*TID/4.)                                                    CON24320
      AI=PI*TID*ALST                                                           CON24330
      AO=PI*GC*ALST                                                            CON24340
      ENHI=1.                                                                  CON24350
      ENHF=1.                                                                  CON24360
      ENHO=1.                                                                  CON24370
      IF (NEI.EQ.0) GO TO 60                                                   CON24380
      DO 50 I=1,NEI                                                            CON24390
      ITEM1=NRNI(I)                                                            CON24400
      ITEM2=ITEM1+NETI(I)-1                                                    CON24410
50    IF ((I.GE.ITEM1).AND.(I.LE.ITEM2)) ENHI=ENI(I)                           CON24420
60    IF (NEE.EQ.0) GO TO 80                                                   CON24430
      DO 70 I=1,NEE                                                            CON24440
      ITEM1=NRNE(I)                                                            CON24450
      ITEM2=ITEM1+NETE(I)-1                                                    CON24460
      IF (I.LT.ITEM.OR.I.GT.ITEM2) GO TO 70                                    CON24470
      ENHO=ENO(I)                                                              CON24480
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      ENHF=ENH(I)                                                       CON24490
70    CONTINUE                                                          CON24500
80    CONTINUE                                                          CON24510
      IF (HETCN.NE.1.) GO TO 90                                         CON24520
      M5=2                                                              CON24530
      WRITE (6,310) M5                                                  CON24540
      WRITE (6,360) UEST,HEFF                                           CON24550
      WRITE (6,370) DGFLM,DLFLM                                         CON24560
      WRITE (6,380) TB2,XNRET                                           CON24570
      WRITE (6,390) BNF,AO,AI                                           CON24580
      WRITE (6,400) ENHI,ENHO                                           CON24590
C$----------                                                           CON24600
C HET 3                                                               CON24610
C                    CALCULATE SUBPROGRAM INITIAL VALUES               CON24620
C                                                                      CON24630
C         AMOLSS & AMOLSC ARE MOLECULAR WEIGHTS USED TO CALCULAT       CON24640
C            AMWAV, THE MIXTURE MOLECULAR WEIGHT.                      CON24650
C         AXO = AREA OF TUBE BANK OPEN TO FLOW/TUBE                    CON24660
C         BB = COOLENT FLOW IN TUBE   LB/HR-FT**2                      CON24670
C         GMAX = STEAM-NC FLOW  LB/FT**2-HR                            CON24680
C         HSTO = LATENT HEAT OF VAPORIZATION OF THE STEAM              CON24690
C         JGAS = INDICATOR FOR TYPE OF N/C GAS PRESENT                 CON24700
C         K = COUNTER FOR NUMBER OF ITERATIONS                         CON24710
C         PSAT = STEAM SATURATION PRESS IN PSI                         CON24720
C         RC = RATIO OF NON-CONDENSIBLES TO TOTAL FLOW                 CON24730
C         RMWNC & RMWSC ARE WEIGHTING FACTORS USED IN DETERMINATION    CON24740
C            OF THE MIXTURE VISCOSITY.                                 CON24750
C         OD = TUBE OUTER DIAMETER                                     CON24760
C         STBAVE = AVERAGE COOLANT TEMP                                CON24770
C         STBI = INLET COOLANT TEMP                                    CON24780
C         STSAT = LOCAL STEAM SAT TEMP  F                              CON24790
C         STWO = TUBE OUTER WALL TEMP                                  CON24800
C         TB2 = OUTLET COOLANT TEMP                                    CON24810
C         WBOTH = SUM OF WS AND WNC                                    CON24820
C         WNC = NON-CONDENSIBLE FLOW LB(MASS)/HR                       CON24830
C         WST = STM FLOW TO ROW BEING CONSIDERED LB(M)/HR              CON24840
C         XNRE = MIXTURE REYNOLDS NUMBER                               CON24850
C                                                                      CON24860
C              VALUES CARRIED INTO THIS ROUTINE                        CON24870
C         COMMON - , AMWNC ,                                           CON24880
C              ORC2 - , AMWNC ,                                        CON24890
C         COMMON/NEW/ - , STBI , JGAS ,                                CON24900
C         PASS LIST - , STSAT ,                                        CON24910
C              SEC3 - , STSAT ,                                        CON24920
C         HET2 - , DLFLM , DGFLM , OD , AXO , WST , WNC ,              CON24930
C                                                                      CON24940
C              FUNCTION ROUTINES CALLED IN HET-3                       CON24950
C         , PSATFN , SMUFN , AMUFN , HFGFN ,                           CON24960
```

```
C                                                                       CON24970
C ZZZ HET-3                                                             CON24980
C--------------                                                         CON24990
90      K=0                                                             CON25000
        WBOTH=WST+WNC                                                   CON25010
        RC=WNC/(WBOTH)                                                  CON25020
        TSAT=STSAT+459.69                                               CON25030
        GMAX=(WBOTH)/AXO                                                CON25040
        PSAT=PSATFN(TSAT)                                               CON25050
        AMOLSS=WST/18.015                                               CON25060
        AMOLSC=WNC/AMWNC                                                CON25070
        AMOLT=AMOLSS+AMOLSC                                             CON25080
        AMWAV=(WBOTH)/AMOLT                                             CON25090
        RMWNC=SQRT(AMWNC)*AMOLSC/AMOLT                                  CON25100
        RMWSC=4.24444*AMOLSS/AMOLT                                      CON25110
        AVIS=(SMUFN(TSAT)*RMWSC+AMUFN(TSAT,JGAS)*RMWNC)/(RMWSC+RMWNC)   CON25120
        HSTO=HFGFN(STSAT)                                               CON25130
        STBAVE=(STB1+TB2)/2.0                                           CON25140
        DELFLM=DLFLM                                                    CON25150
        DLGFLM=DGFLM                                                    CON25160
        STWO=STSAT-DELFLM-DLGFLM                                        CON25170
        STFO=(STSAT+STWO)/2.0                                           CON25180
        XNRE=OD*(WBOTH)/(AXO*3600.*AVIS)                                CON25190
        IF (HETCN.NE.1.) GO TO 100                                      CON25200
        M5=3                                                            CON25210
        WRITE (6,310) M5                                                CON25220
        WRITE (6,410) GMAX,PSAT                                         CON25230
        WRITE (6,420) AMOLSS,AMOLSC,AMOLT                               CON25240
        WRITE (6,430) RMWNC,RMWSC                                       CON25250
        WRITE (6,440) AVIS,HSTO,XNRE                                    CON25260
        WRITE (6,450) STBAVE,STFO,STWO                                  CON25270
        WRITE (6,460) DELFLM,DLGFLM                                     CON25280
C$--------------                                                        CON25290
C HET 5                                                                 CON25300
C                       COLBY J FACTOR CALCULATION AND BRANCH           CON25310
C                                                                       CON25320
C         WNCI = TOTAL WEIGHT OF NONCOND ENTERING CONDENSER             CON25330
C              IF NO NONCOND, THEN SKIP DIFUSIVITY CALCULATION.         CON25340
C                                                                       CON25350
C ZZZ HET-5                                                             CON25360
C--------------                                                         CON25370
100     CONTINUE                                                        CON25380
        COLBJ=EXP(0.53883-0.544*ALOG(XNRE))                             CON25390
        IF (HETCN.NE.1.) GO TO 110                                      CON25400
        M5=5                                                            CON25410
        WRITE (6,310) M5                                                CON25420
        WRITE (6,470) COLBJ,WNC                                         CON25430
110     IF (WNC.EQ.0.) GO TO 120                                        CON25440
```

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C$-------------
C HET 6
C                 PREPARATION FOR CALL TO SUBROUTINE DFSVTY;
C                 CALCULATE SCHMIDT NUMBER AND PARAMETER CJ.
C
C            THIS SECTION IS BRANCHED AROUND IF NO NONCOND GASSES ARE
C                 PRESENT.
C
C        AMWAV = STEAM-N/C GAS MIXTURE MOLECULAR WEIGHT
C        AVIS = AVG VISCOSITY OF STEAM-N/C GAS MIXTURE
C        CJ = PARAMETER USED IN CALCULATION OF THE HEAT TRANSFER COEF.
C           SEE EQUATION 11 IN APP 8
C        DD = DIFFUSIVITY (SEE NOTE)
C        DDG = DUMMY PASSING PARAMETER FOR SUB DSFVTY
C        E2OK = N/C GAS FORCE CONSTANT (SEE SUB DSFVTY)
C        PATM = SAT PRESS IN ATM
C        PGB = NONCOND PARTIAL PRESSURE
C        PSAT = STEAM SATURATION PRESS PSI
C        R = N/C GAS COLLISION DIAMETER (SEE SUB DSFVTY)
C        TSAT = STEAM SATURATION TEMP
C        TSATK = SATURATION TEMP IN DEGREES KELVIN
C        XNSCH = SCHMIDT NUMBER
C
C            NOTE:  PATM, PGB, AND TSATK ARE USED FOR CALL TO DFSVTY
C                   SEE NOTE IN HET-3, BUT REM PGB IS USED AGAIN
C                   IN HET-12.
C
C            NOTE:  18.015 IS THE MOLECULAR WEIGHT OF WATER
C                   2.655 IS THE STEAM COLLISION DIAMETER IN ANGSTROMS
C                   363. IS THE STEAM FORCE CONSTANT USED IN DFSVTY
C
C            NOTE:  ONLY DG (DIFFUSIVITY IN CM**2/SEC) IS MODIFIED IN
C                   SUBROUTINE DFSVTY.
C
C            NOTE:  0.258 CONVERTS UNITS OF DIFUSIVITY FROM
C                   CM**2/SEC TO FT**2/HR, AND 3600 CONVERTS
C                   VISCOSITY  FROM LB(F)-HR TO LB(F)-SEC.
C                   IN XNSCH CALC, .258*3600 = 928.8
C
C
C ZZZ HET-6
C-------------
      PATM=PSAT/14.7
      PGB=PSAT*(AMOLSC/AMOLSS)
      TSATK=TSAT/1.8
      CALL DFSVTY (TSATK,PATM,18.015,AMWNC,2.655,R2(JGAS),363.,E2OK(JGAS
     1),0.,0.,DG,DGG)
      XNSCH=(AVIS*TSAT*10.73/((PSAT+PGB)*AMWAV*DG))*928.8
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      CJ=COLBJ*GMAX/(XNSCH**0.066667)                                   CON25930
      IF (HETCN.NE.1.) GO TO 120                                        CON25940
      M5=6                                                              CON25950
      WRITE (6,310) M5                                                  CON25960
C$----------                                                            CON25970
C HET 7                                                                 CON25980
C                   BEGIN ITERATIVE CALCULATIONS FOR:                   CON25990
C                         HEAT TRANSFER COEF                            CON26000
C                     TEMP DROP ACROSS LIQUID FILM                      CON26010
C                   TEMP DROP ACROSS N/C FILM (IF ANY)                  CON26020
C                                                                       CON26030
C              THE PROGRAM CONTINUES TO RETURN HERE UNTIL ONE           CON26040
C              OR MORE OF THE FOLLOWING CONDITIONS ARE MET:             CON26050
C                   1)  CHANGE IN THE CALCULATED HEAT TRANSFER COEF IS  CON26060
C                       LESS THAN  OF THE PREVIOUS VALUE AND AT LEAST   CON26070
C                       FOUR ITERATIONS HAVE BEEN MADE.                 CON26080
C                   2)  CHANGE IN THE CALCULATED TEMP ACROSS THE LIQUID CON26090
C                       FILM IS LESS THAN .01 DEGREES AND THE CHANGE    CON26100
C                       IN CALCULATED TEMP DIFF ACROSS THE GAS FILM     CON26110
C                       IS LESS THEN .001 DEGREES.                      CON26120
C                   3)  TEN ITERATIONS HAVE BEEN COMPLETED.             CON26130
C                                                                       CON26140
C         AI = INTERNAL SURFACE AREA OF ONE TUBE  FT**2                 CON26150
C         AO = EXTERNAL SURFACE AREA OF ONE TUBE  FT**2                 CON26160
C         BB = COOLANT FLOW IN TUBE  LBM/HR-FT**2                       CON26170
C         BMU = COOLANT VISCOSITY  LBM/HR-FT                            CON26180
C         BNF = TUBE FLOODING FACTOR                                    CON26190
C         CBI = COOLANT CONCENTRATION                                   CON26200
C         ENHI = INTERNAL FILM COEF ENHANCEMENT FACTOR                  CON26210
C         ENHO = EXTERNAL FILM COEF ENHANCEMENT FACTOR                  CON26220
C         RIN = RESISTANCE TO HEAT TRANSFER DUE INNER FILM              CON26230
C         TID = TUBE ID  FT                                             CON26240
C         OD = TUBE OD  FT                                              CON26250
C         SHBI = SPECIFIC HEAT OF COOLANTBTU/LBM-F                      CON26260
C         SHI = INTERNAL FILM HEAT TRANSFER COEF  BTU/HR-FT**2-F        CON26270
C         SHMK = EXTERNAL FILM HEAT TRANSFER COEF  BTU/HR-FT**2-F       CON26280
C         SKB = THERMAL CONDUCTIVITY OF THE COOLANT  BTU-FT/HR-FT**2-F  CON26290
C         SKBO = THERMAL CONDUCTIVITY OF OUTER LIQUID FILM              CON26300
C         STBAVE = AVE COOLANT TEMP.                                    CON26310
C         STFO = AVE TEMP OF OUTER LIQUID FILM (SEE NOTE)               CON26320
C         STSAT = LOCAL SAT STM TEMP                                    CON26330
C         TB2 = OUTLET COOLANT TEMP.  (SEE NOTE ON TB2 IN HET-3)        CON26340
C         WB = COOLANT FLOW RATE PER TUBE  LBM/HR                       CON26350
C         XNREB = REYNOLDS NUMBER OF COOLANT                            CON26360
C         XNPRB = PRANDTL NUMBER OF COOLANT                             CON26370
C                                                                       CON26380
C                   NOTE: SHMK IS CALCULATED FIRST WITHOUT TAKING FLOODING CON26390
C                         INTO ACCOUNT.  SEE NUSSELT EQN PG. 16.        CON26400
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C                                                                       CON26410
C                    NOTE: STFO  IS INITIALLY GUESSED BASED ON STWO WHICH  CON26420
C                          IS IN TURN BASED ON DLFLM AND DGFLM.  DGFLM AND  CON26430
C                          DLFLM ARE INITIALIZED BY DATA STATEMENT UPON     CON26440
C                          ENTERING THIS SUBROUTINE.  ALL FOUR OF           CON26450
C                          THESE VARIABLES ARE UPDATED BELOW.               CON26460
C                                                                           CON26470
C                                                                           CON26480
C  ZZZ HET-7                                                                CON26490
C-------------                                                              CON26500
120     TB2=STSAT-(STSAT-STBI)/EXP(UEST*AO/(WB*CPFN(CBI,STBAVE)))          CON26510
        STBAVE=(STBI+TB2)/2.                                                CON26520
        SKBO=SKBFN(0.,STFO)                                                 CON26530
        SKB=SKBFN(CBI,STBAVE)                                               CON26540
        BMU=BMUFN(CBI,STBAVE)                                               CON26550
        SHBI=CPFN(CBI,STBAVE)                                               CON26560
        XNREB=TID*BB/BMU                                                    CON26570
        XNPRB=SHBI*BMU/SKB                                                  CON26580
        SHI=0.023*(XNREB)**0.8*XNPRB**0.33333*(SKB/TID)*ENHI                CON26590
        RIN=AO/(SHI*AI)                                                     CON26600
        SHMK=0.725*(SKBO**3*ROEFN(0.0,STFO)**2*HFGFN(STFO)*41695040.0/(BMCON26610
       1UFN(0,STFO)*OD*DELFLM))**.25*ENHO                                   CON26620
C                                                                           CON26630
C   THIS IS THE PLACE TO ENTER CORRECTIONS TO THE EXTERNAL FILM COEFF. THECON26640
C   FOLLOWING IS A CORRECTION ACCORDING TO FUJII, ET. AL, TO ACCOUNT FOR  CON26650
C   THE EFFECTS OF VAPOR SHEAR AT HIGH VAPOR REYNOLDS NUMBERS.            CON26660
C                                                                           CON26670
        SHMK1=SHMK                                                          CON26680
        ANUS=SHMK*OD/SKBO                                                   CON26690
        EMUL=BMUFN(0.,STSAT)                                                CON26700
        EMUS=SMUFN(TSAT)*3600.                                              CON26710
        RHOL=ROEFN(0.,STSAT)                                                CON26720
        RHOS=1./VGFN(TSAT,PSAT)                                             CON26730
        VISRAT=(EMUS/RHOS)/(EMUL/RHOL)                                      CON26740
        RETP=XNRE*VISRAT                                                    CON26750
        TERM=SQRT(RETP)/ANUS                                                CON26760
        IF (TERM.LT..278) GO TO 130                                         CON26770
        ANUSP=1.24*(ANUS**0.8)*(RETP**0.1)                                  CON26780
        GO TO 140                                                           CON26790
130     ANUSP=ANUS*0.70/0.725                                               CON26800
140     SHMKP=ANUSP*SKBO/OD                                                 CON26810
        SHMK=SHMKP                                                          CON26820
C                                                                           CON26830
C                                                                           CON26840
        IF (HETCN.NE.1.) GO TO 150                                          CON26850
        M5=7                                                                CON26860
        WRITE (6,310) M5                                                    CON26870
        WRITE (6,480) TB2,STBAVE                                            CON26880
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      WRITE (6,490) SKBO,SKB                                              CON26890
      WRITE (6,500) BMU,SHBI                                              CON26900
      WRITE (6,510) XNREB,XNPRB                                           CON26910
      WRITE (6,520) SHI,RIN,SHMK                                          CON26920
C$-------------                                                           CON26930
C  HET 9                                                                  CON26940
C                    TEST FOR TUBE FLOODING, MODIFY                       CON26950
C                        SHMK AS NEEDED                                   CON26960
C                                                                         CON26970
C               THIS SECTION MODIFIES THE EXTERNAL HEAT TRANSFER          CON26980
C                 COEF GIVEN BY NUSSELT EQN. FOR TUBE FLOODING.           CON26990
C                                                                         CON27000
C          BNF = CALCULATED TUBE FLOODING FACTOR (SEE NOTE BELOW)         CON27010
C          FDAVE = INPUT VALUE OF TUBE FLOODING FACTOR (SEE NOTE BELOW)   CON27020
C          FDAVN & FDAVM ARE INTERMEDIATE VALUES USED LATER.              CON27030
C          FOUL = TUBE FOULING FACTOR INPUT BY USER                       CON27040
C          RFACT = SUM OF THERMAL RESISTANCES NEGLECTING GAS FILM         CON27050
C          RIN = RESESTANCE TO HEAT X-FER DUE TO INTERNAL FILM            CON27060
C          SHNF = EXTERIOR HEAT X-FER COEF, SHMK MODIFIED FOR RAIN        CON27070
C          SHWINV = INVERSE OF WALL HEAT TRANSFER COEF                    CON27080
C                                                                         CON27090
C                    NOTE:ADD CALC FOR FDAVE     CURRENTLY UNDEF          CON27100
C                                                                         CON27110
C                    NOTE:CALC FOR FDAVM AND FDAVN SHOULD BE MOVED        CON27120
C                         ABOVE LINE 40.                                  CON27130
C                                                                         CON27140
C                                                                         CON27150
C  ZZZ HET-9                                                              CON27160
C-------------                                                            CON27170
150   CONTINUE                                                            CON27180
C                                                                         CON27190
C       INUNDATION EFFECT MAY BE BYPASSED BY SETTING BNF = 1.             CON27200
C                                                                         CON27210
C     BNF = 1.                                                            CON27220
      IF (FDAVE.LT.0..OR.BNF.LT.2.) GO TO 160                             CON27230
      FDAVN=0.6*FDAVE+(1.-0.5647*FDAVE)/BNF**.20                          CON27240
      FDAVM=0.6*FDAVE+(1.-0.5647*FDAVE)/(BNF-1.)**.20                     CON27250
      SHNF=SHMK*(BNF*FDAVN-(BNF-1.)*FDAVM)                                CON27260
      GO TO 170                                                           CON27270
160   SHNF=0.95*(BNF**0.9-(BNF-1.)**0.9)*SHMK                             CON27280
170   RFACT=RIN+SHWINV+FOUL+1./SHNF                                       CON27290
      IF (HETCN.NE.1.) GO TO 180                                          CON27300
      M5=9                                                                CON27310
      WRITE (6,310) M5                                                    CON27320
      WRITE (6,530) FDAVN,FDAVM                                           CON27330
      WRITE (6,540) SHNF,RFACT                                            CON27340
C$-------------                                                           CON27350
C  HET 10                                                                 CON27360
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C               CONTROL PASSES FROM THIS ROUTINE TO ONE OF TWO PLACES,      CON27850
C               LINE 40 (HET-7) TO START A NEW ITERATION, OR TO             CON27860
C               LINE 170 (HET-13) TO TERMINATE THIS HETTRN CALL             CON27870
C               WHEN ONE OF THE FOLLOWING CRITERIA ARE MET:                 CON27880
C                    1) 10 ITERATIONS COMPLETED WITHOUT CONDITION 2 BEING   CON27890
C                       MET.                                                CON27900
C                    2) CHANGE IN HEAT TRANSFER COEF .LT. 1 PERCENT         CON27910
C                       BETWEEN SUCCESSIVE ITERATIONS.                      CON27920
C                                                                           CON27930
C          DELFLM = SAVED VALUE OF DLFLM,USED ONLY FOR PRINT                CON27940
C          DGFLM = TEMP DROP ACROSS GAS FILM, SET TO 0 HERE                 CON27950
C          DLFLM = TEMP DROP ACROSS LIQUID CONDENSATE FILM                  CON27960
C          K = COUNTER FOR NUMBER OF ITERATIONS                             CON27970
C          RFACT = SUM OF THERMAL RESISTANCES                               CON27980
C          ROUT = EXTERNAL FILM RESISTANCE. (SEE NOTE)                      CON27990
C          OD = TUBE OD                                                     CON28000
C          SHNF = EXTERNAL FILM HEAT X-FER COEF                             CON28010
C          SKBO = THERMAL CONDUCTIVITY OF EXTERNAL LIQUID FILM              CON28020
C          STCO = TEMP AT SURFACE OF OUTER LIQUID FILM                      CON28030
C          STFO = AVE TEMP OF OUTER LIQUID FILM                             CON28040
C          STBAVE = AVE COOLANT TEMP                                        CON28050
C          STSAT = STEAM SATURATION TEMP                                    CON28060
C          STWO = TUBE OUTER WALL TEMP                                      CON28070
C          UEST = VALUE OF UEST FROM LAST ITERATION                         CON28080
C          UESTS = SAVED VALUE OF UEST, USED ONLY FOR PRINT                 CON28090
C          UTEST = TUBE HEAT X-FER COEF.                                    CON28100
C          XNU = NUSSELT NUMBER                                             CON28110
C                                                                           CON28120
C                    NOTE: CONSIDER REQUIREMENT FOR MINIMUM OF              CON28130
C                          FOUR ITERATIONS PRIOR TO UPDATING UEST.  COULD   CON28140
C                          BE AN ALLOWANCE FOR DELFLM TO CATCH UP IN        CON28150
C                          CONVERGENCE.  IF SO, TEST DELFLM FOR ITS         CON28160
C                          OWN CONVERGENCE, ELIMINATE MIN OF 4 ITERATIONS.  CON28170
C                                                                           CON28180
C                    NOTE: ROUT WILL BE REDEFINED AS 1/ROUT                 CON28190
C                          IN HET-13 PRIOR TO EXIT FROM HETTRN              CON28200
C                                                                           CON28210
C                                                                           CON28220
C ZZZ HET-11                                                                CON28230
C---------------                                                            CON28240
      ROUT=1./SHNF                                                          CON28250
      UTEST=1./RFACT                                                        CON28260
      XNU=SHNF*OD/SKBO                                                      CON28270
      IF (ABS(UEST-UTEST)/UTEST.LT..01) GO TO 290                           CON28280
      UESTSV=UEST                                                           CON28290
      UEST=UTEST                                                            CON28300
      IF (K.GT.4) UEST=0.5*(UTEST+UESTSV)                                   CON28310
      STWO=STSAT-(STSAT-STBAVE)*UTEST/SHNF                                  CON28320
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C                    CALCULATE LOG-MEAN TEMP-DIFFERENCE                    CON27370
C                                                                          CON27380
C                 THIS CALCULATION IS COMPLETED ONCE DURING EACH           CON27390
C                 ITERATION.  UPON COMPLETION, A TEST IS MADE              CON27400
C                 FOR THE PRESENCE OF N/C GASSES.  IF ANY                  CON27410
C                 GAS IS PRESENT, PROGRAM BRANCES TO LINE 110 (HET-12).    CON27420
C                 IF NOT, THEN PROGRAM FLOWS TO HET-11, BELOW.             CON27430
C                                                                          CON27440
C           ALMDT = LMTD                                                   CON27450
C           HOMCO = TEMP DIFF BETWEEN STEAM AND COOLANT OUTLET             CON27460
C           HOMCI = TEMP DIFF BETWEEN STEAM AND COOLANT AT INLET           CON27470
C           JRC = PRINT CONTROL FLAG                                       CON27480
C           RODT = RATIO OF HOMCI TO HOMCO                                 CON27490
C           STBI = COOLANT INLET TEMP                                      CON27500
C           STSAT = STEAM SATURATION TEMP                                  CON27510
C           TB2 = COOLANT OUTLET TEMP                                      CON27520
C           WNCI = TOTAL N/C GAS FLOW TO CONDENSER                         CON27530
C                                                                          CON27540
C                                                                          CON27550
C ZZZ HET-10                                                               CON27560
C--------------                                                            CON27570
180    HOMCI=STSAT-STBI                                                    CON27580
       HOMCO=STSAT-TB2                                                     CON27590
C                                                                          CON27600
C      IF (HOMCO.LT.1.E-15) WRITE(6,20600) HOMCI,HCMCO                     CON27610
C      IF (HOMCI.LT.1.E-15) WRITE(6,20600) HOMCI,HOMCO                     CON27620
       IF (HOMCO.LT.1.E-15) HOMCO=1.E-15                                   CON27630
C                                                                          CON27640
       RODT=HCMCI/HOMCO                                                    CON27650
C                                                                          CON27660
C      IF INLET/OUTLET DELTA T RATIO IS NEAR 1.0, ALMTD = ARITH. AVG.      CON27670
       IF (RODT.GT.1.1) GO TO 190                                          CON27680
       ALMTD=0.5*(HOMCI+HOMCO)                                             CON27690
       IF (HETCN.EQ.1.) WRITE (6,670) STSAT,STBI,TB2,LJ,IR,II              CON27700
       GO TO 200                                                           CON27710
190    ALMTD=(HOMCI-HOMCO)/ALOG(RODT)                                      CON27720
200    CONTINUE                                                            CON27730
       IF (HETCN.NE.1.) GO TO 210                                          CON27740
       M5=10                                                               CON27750
       WRITE (6,310) M5                                                    CON27760
       WRITE (6,550) HOMCI,HOMCO                                           CON27770
       WRITE (6,560) RODT,ALMTD                                            CON27780
210    IF (WNC.NE.0.) GO TO 230                                            CON27790
C--------------                                                            CON27800
C HET 11                                                                   CON27810
C                    CALCULATE FINAL HEAT TRANSFER PARAMETERS              CON27820
C                    FOR NO N/C GASSES ENTERING THE CONDENSER.             CON27830
C                                                                          CON27840
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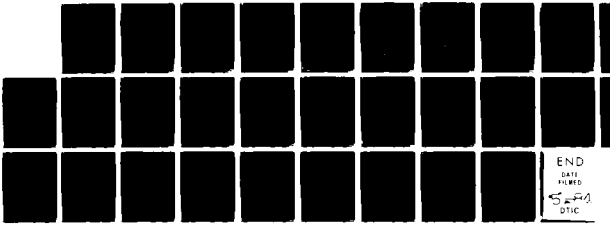
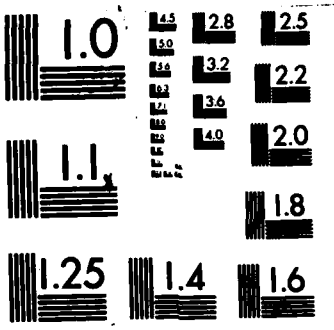
AD-A138 568 MARINE STEAM CONDENSER DESIGN OPTIMIZATION(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA T M BUCKINGHAM DEC 83 3/3

UNCLASSIFIED F/G 13/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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      STCO=STSAT                                                        CON28330
      STFO=(STCO+STWO)/2.                                               CON28340
      DGFLM=0.                                                          CON28350
      DLFLM=STCO-STWO                                                   CON28360
      DELFLM=DLFLM                                                      CON28370
      K=K+1                                                             CON28380
      IF (HETCN.NE.1.) GO TO 220                                        CON28390
      M5=11                                                             CON28400
      WRITE (6,310) M5                                                  CON28410
      WRITE (6,570) UTEST,UESTSV                                        CON28420
      WRITE (6,580) XNU,ROUT                                            CON28430
      WRITE (6,590) STWO,STCO,STFO                                      CON28440
      WRITE (6,600) DGFLM,DLFLM                                         CON28450
220   IF (K.LT.20) GO TO 120                                            CON28460
      WRITE (6,640) UESTSV,UTEST                                        CON28470
      GO TO 290                                                         CON28480
C$-------------                                                         CON28490
C HET 12                                                                CON28500
C                   CALCULATE FINAL HEAT TRANSFER PARAMETERS            CON28510
C                   FOR N/C GASSES ENTERING CONDENSER                   CON28520
C                                                                       CON28530
C             PROGRAM CONTROL COMES HERE FROM HET-10. CONTROL PASSES    CON28540
C             FROM HERE TO ONE OF TWO PLACES, EITHER LINE 40 (HET-7) TO CON28550
C             BEGIN THE NEXT ITERATION, OR TO LINE 170 (HET-13) WHEN    CON28560
C             ONE OF THE FOLLOWING CONDITIONS ARE MET:                  CON28570
C                   1) 10 ITERATIONS HAVE BEEN COMPLETED PRIOR TO MEETINGCON28580
C                      CONDITION 2.                                     CON28590
C                   2) CHANGES IN UEST .LT. .001, IN DLFLM .LT.         CON28600
C                      .01 AND IN DGFLM .LT. .001                       CON28610
C                                                                       CON28620
C        ALMTD = LMTD                                                   CON28630
C        BONE = CONSTANT IN SOLUTION OF EQN 11A, APP A.                 CON28640
C        CJ - SEE BONE                                                  CON28650
C        CONE - SEE BONE                                                CON28660
C        DELFLM = DLFLM FROM PREVIOS ITERATION                          CON28670
C        DELTAU = HEAT DUTY ON HEAT X-FER SURFACE                       CON28680
C        DENOM =                                                        CON28690
C        DGFLM = TEMP DIFF ACROSS N/C GAS FILM                          CON28700
C        DLFLM = TEMP DIFF ACROSS CONDENSATE FILM                       CON28710
C        DLGFLM = DGFLM FROM PREVIOS ITERATION                          CON28720
C        DTDP = INVERSE OF DPDT (SEE NOTE)                              CON28730
C        HEFF = N/C GAS HEAT X-FER COEF                                 CON28740
C        HSTO = STEAM LATENT HEAT OF VAPORIZATION                       CON28750
C        IBT = PRINT CONTROL                                            CON28760
C        IR = CURRENT ROW NUMBER                                        CON28770
C        K = ITERATION COUNTER                                          CON28780
C        LJ = CURRENT SECTOR NUMBER                                     CON28790
C        PGB = PARTIAL PRESSURE OF N/C GASSES                           CON28800
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C          RFACT = SUM OF THERMAL RESISTANCES NEGLECTING N/C GASSES          CON28810
C          ROUT = EXTERNAL HEAT X-FER COEF                                  CON28820
C          OD = TUBE OD                                                     CON28830
C          SHNF = EXTERNAL LIQUID FILM HEAT X-FER COEF                      CON28840
C          SKBO = THERMAL CONDUCTIVITY OF OUTER LIQUID                      CON28850
C          STBAVE = AVG COOLANT TEMP                                        CON28860
C          STCO = TEMP AT SURFACE OF OUTER LIQUID FILM                      CON28870
C          STFC = OUTER LIQUID FILM AVG TEMP                                CON28880
C          STSAT = STM SATURATION TEMP                                      CON28890
C          STWO = TUBE OUTER WALL TEMP                                      CON28900
C          T = AVG LIQUID FILM TEMP IN RANKIN                               CON28910
C          TDIF = TEMP DIFF BETWEEN SAT STM AND AVE COOLANT TEMP            CON28920
C          TSAT = STM SAT TEMP IN RANKIN                                    CON28930
C          UEST & UESTSV - VALUE OF UTEST AND UEST FROM PREVIOS ITERATION   CON28940
C          UTEST = OVERALL HEAT X-FER COEF.                                 CON28950
C          XNU = NUSSELT NUMBER                                             CON28960
C                                                                           CON28970
C                                                                           CON28980
C  ZZZ HET-12                                                               CON28990
C--------------                                                             CON29000
230     CONTINUE                                                            CON29010
        M5=12                                                               CON29020
        IF (HETCN.EQ.1.) WRITE (6,310) M5                                   CON29030
        STCO=STSAT-DLGFLM                                                   CON29040
        T=(TSAT+STCO+459.69)/2.0                                            CON29050
        DTDP=1./(((6452.562+2.*837533.2/T)/T**2)*EXP(14.15012-(6452.562+83  CON29060
      17533.2/T)/T))                                                        CON29070
        BONE=-1.*(CJ*HSTO/ALMTD+(PGB*DTDP/ALMTD+1.)/RFACT)                  CON29080
        CONE=CJ*HSTO/(ALMTD*RFACT)                                          CON29090
        UTEST=(-SQRT(BONE**2-4.*CONE)-BONE)/2.                              CON29100
        DENOM=1.-UTEST*RFACT                                                CON29110
        IF (DENOM.GT.1.E-7) GO TO 240                                       CON29120
        HEFF=1.E8                                                           CON29130
        GO TO 250                                                           CON29140
240     HEFF=UTEST/DENOM                                                    CON29150
250     CONTINUE                                                            CON29160
        ROUT=(HEFF+SHNF)/(HEFF*SHNF)                                        CON29170
        TDIF=STSAT-STBAVE                                                   CON29180
        IF (TDIF.GT.0) GO TO 260                                            CON29190
        IF (IBT.EQ.0) WRITE (6,660) STSAT,STBAVE,LJ,IR                      CON29200
        IBT=1                                                               CON29210
        TDIF=.1                                                             CON29220
260     CONTINUE                                                            CON29230
        DELTAU=TDIF*UTEST                                                   CON29240
        DGFLM=DELTAU/HEFF                                                   CON29250
        DLFLM=DELTAU/SHNF                                                   CON29260
        STCO=STSAT-DGFLM                                                    CON29270
        STWO=STCO-DLFLM                                                     CON29280
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      STFO=(STCO+STWO)/2.
      XNU=OD/(SKBO*ROUT)
      IF (ABS(UTEST-UEST)/UTEST.LT..001) GO TC 270
      IF (HETCN.EQ.1.) WRITE (6,610) K
      DELFLM=DLFLM
      DLGFLM=DGFLM
      UESTSV=UEST
      UEST=UTEST
      K=K+1
      IF (K.GT.4) UEST=0.5*(UTEST+UESTSV)
      IF (K.LT.10) GO TO 120
      IF (HETCN.EQ.1.) WRITE (6,640) UESTSV,UTEST
      GO TO 290
270   IF (ABS(DELFLM-DLFLM).LT..01) GO TO 280
      IF (HETCN.EQ.1.) WRITE (6,620) K
      DELFLM=DLFLM
      DLGFLM=DGFLM
      K=K+1
      IF (K.LT.10) GO TO 120
      WRITE (6,650) DELFLM,LJ,IR
280   IF (ABS(DLGFLM-DGFLM).LT..001) GO TO 290
      DLGFLM=DGFLM
      K=K+1
      IF (K.LT.20) GO TO 120
      WRITE (6,630) DLGFLM,UEST,UTEST,LJ,IR
C$-------------
C HET 13
C                    FINAL CALCULATIONS; EXIT HETTRN
C
C         HEFF = SEE XHEFF
C         TB2 = TUBE OUTLET TEMP
C         VNF = OVERAL HEAT X-FER COEF
C         VPSHH = OUTLET COOLANT TEMP
C         XHEFF = N/C GAS FILM HEAT X-FER COEF
C
C                    NOTE:HERE VALUES OF HEFF, UEST, AND TB2 ARE PASSED
C                         OUT OF HETTRN AND SAVED, BUT NOT RE-USED
C                         TO START NEXT ITERATICN.  SEE NOTES IN
C                         HET-2 AND HET-3.
C
C ZZZ HET-13
C-------------
      M5=13
      WRITE (6,310) M5
290   VNF=UTEST
      ROUT=1./ROUT
      IF (IR.GT.1) GO TO 300
      UEST1=UEST
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      HEFF1=HEFF                                                        CON29770
      DLFLM1=DLFLM                                                      CON29780
      DGFLM1=DGFLM                                                      CON29790
      TB21=TB2                                                          CON29800
      XNRE1=XNRE                                                        CON29810
  300 CONTINUE                                                          CON29820
      UESTSV=UEST                                                       CON29830
      HEFSV=HEFF                                                        CON29840
      DGFLMS=DGFLM                                                      CON29850
      DLFLMS=DLFLM                                                      CON29860
      TB2SV=TB2                                                         CON29870
      XNRESV=XNRE                                                       CON29880
      RETURN                                                            CON29890
C$    TOP OF PAGE CHARACTOR FOR USE WITH $PRT                           CON29900
  310 FORMAT (1H0,17HIN HETTERN   -HET,I2)                              CON29910
  320 FORMAT (1H ,4HRGW=,I4,10H  SECTOR =,I4)                           CON29920
  330 FORMAT (1H ,3HOD=,F6.4,6H  TID=,F6.4)                             CON29930
  340 FORMAT (1H ,7HSHWINV=,E10.3,8H  STSAT=,E10.3)                     CON29940
  350 FORMAT (1H ,4HWST=,F8.2,6H  WNC=,F8.2)                            CON29950
  360 FORMAT (1H ,5HUEST=,E10.3,7H  HEFF=,E10.3)                        CON29960
  370 FORMAT (1H ,6HDGFLM=,E10.3,8H  DLFLM=,E10.3)                      CON29970
  380 FORMAT (1H ,4HTB2=,E10.3,8H  XNRET=,E10.3)                        CON29980
  390 FORMAT (1H ,4HBNF=,E10.3,5H  AO=,E10.3,5H  AI=,E10.3)             CON29990
  400 FORMAT (1H ,5HEHNI=,E10.3,7H  EHNO=,E10.3)                        CON30000
  410 FORMAT (1H ,5HGMAX=,E10.3,7H  PSAT=,E10.3)                        CON30010
  420 FORMAT (1H ,7HAMOLSS=,E10.3,9H  AMOLSC=,E10.3,8H  AMOLT=,E10.3)   CON30020
  430 FORMAT (1H ,6HRMWNC=,E10.3,8H  RMWSC=,E10.3)                      CON30030
  440 FORMAT (1H ,5HAVIS=,E10.3,7H  HSTO=,E10.3,7H  XNRE=,E10.3)        CON30040
  450 FORMAT (1H ,7HSTBAVE=,E10.3,7H  STFO=,E10.3,7H  STWO=,E10.3)      CON30050
  460 FORMAT (1H ,7HDELFLM=,E10.3,9H  DLGFLM=,E10.3)                    CON30060
  470 FORMAT (1H ,6HCOLBJ=,E10.3,6H  WNC=,E10.3)                        CON30070
  480 FORMAT (1H ,4HTB2=,E10.3,9H  STBAVE=,E10.3)                       CON30080
  490 FORMAT (1h ,5HSKBO=,E10.3,6H  SKB=,E10.3)                         CON30090
  500 FORMAT (1H ,4HBMU=,E10.3,7H  SHBI=,E10.3)                         CON30100
  510 FORMAT (1H ,6HXNREB=,E10.3,8H  XNPRB=,E10.3)                      CON30110
  520 FORMAT (1H ,4HSHI=,E10.3,6H  RIN=,E10.3,5HSHMK=,E10.3)            CON30120
  530 FORMAT (1H ,6HFDAVN=,E10.3,8H  FDAVM=,E10.3)                      CON30130
  540 FORMAT (1H ,5HSHNF=,E10.3,8H  RFACT=,E10.3)                       CON30140
  550 FORMAT (1H ,6HHOMCI=,E10.3,8H  HOMCO=,E10.3)                      CON30150
  560 FORMAT (1H ,5HRODT=,E10.3,8H  ALMTD=,E10.3)                       CON30160
  570 FORMAT (1H ,6HUTEST=,E10.3,8H  ESTSV=,E10.3)                      CON30170
  580 FORMAT (1H ,4HXNU=,E10.3,7H  ROUT=,E10.3)                         CON30180
  590 FORMAT (1H ,5HSTWO=,E10.3,7H  STCO=,E10.3,7h  STFO=,E10.3)        CON30190
  600 FORMAT (1H ,6HDGFLM=,E10.3,8H  DLFLM=,E10.3)                      CON30200
  610 FORMAT (1H ,50HCONVERGENCE NOT YET ACHIEVED ON UEST IN HET-12, K=,CON30210
     1I4)                                                               CON30220
  620 FORMAT (1H ,52HCONVERGENCE NOT YET ACHIEVED ON DELFLM IN HET-12, KCON30230
     1=,I4)                                                             CON30240
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  630   FORMAT (1HO,36H NO CONVERGENCE IN FILM TEMPERATURES,8H DLGFLM=,E12CON30250
     1.5,7H UEST =,E12.5,8H UTEST =,E12.5/10H SECTOR = ,I5,5H ROW=,I5)  CON30260
  640   FORMAT (1HO,32H NO CONVERGENCE IN UESY, UEST = ,E12.5,9H UTEST = ,CON30270
     1E12.5)                                                            CON30280
  650   FORMAT (1HO,34H NO CONVERGENCE IN DELFLM, DELFLM=,E12.5,8H SECTOR=CON30290
     1,I5,5H ROW=,I5)                                                   CON30300
  660   FORMAT (1HO,53H  SAT STEAM TEMP LESS THAN AVG BRINE TEMP,     STSATCON30310
     1 =,E12.5,10H STBAVE = ,E12.5,9H    SECTOR,I3,6H    ROW,I4)        CON30320
  670   FORMAT (1HO,47H INPET/OUTLET DELTA T RATIO IS NEAR 1.0, STSAT=,E13CON30330
     1.6,7H  STBI=,E13.6,6H  TB2=,E13.6,8H  SECTOR,I3,5H  ROW,2I5)      CON30340
        END                                                             CON30350
C                                                                       CON30360
C*****************************************************************     CON30370
C*****************************************************************     CON30380
C                                                                       CON30390
      SUBROUTINE COOLEX (TBDRYC,WCNDAV,SBFLOC,WSOUT)                    CON30400
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,CON30410
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNCTDCON30420
     2T,BNDRAC,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR                      CON30430
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON30440
     1TSAT1,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON30450
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON30460
     3,WSI,PFILL                                                        CON30470
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMDOT(10CON30480
     1O)                                                                CON30490
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNC,VEL2,FR              CON30500
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,AOC,SUMQC,SDIC,SDOC,UBARW,SMWBC,CON30510
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AOT,BUNWT,AVTBI,AVTB2,WTSTC,VOLC CON30520
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST                         CON30530
      COMMON /COOL1/ VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100CON30540
     1),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),CON30550
     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QOAC(100),CCON30560
     3UMDPC(100)                                                        CON30570
      COMMON /COOL/ IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,TCON30580
     1B2C,ENHIC,ENHOC,ENHFC,SHWINC,WBC                                  CON30590
      DIMENSION R2(3),E20K(3),VPSHC(100)                                CON30600
      DATA HEFF,UEST,DGFLM,DLFLM/2100.,700.,0.05,2.0/                   CON30610
      DATA R2,E20K/3.617,3.996,3.838,97.0,109.0,140.75/                 CON30620
C                                                                       CON30630
CCCCC            ***VARIABLES USED IN COOLER***                         CON30640
CCCCC                                                                   CON30650
CCCCC                                                                   CON30660
CCCCC     ALMTDC = LMTD FOR A ROW IN COOLER                             CON30670
CCCCC     AOC = OUTER SURFACE AREA OF A TUBE  FT**2                     CON30680
CCCCC     AHOLES = THE X-SECTIONAL AREA OCCUPIED BY THE TUBES           CON30690
CCCCC     AXOC = AREA OPEN TO FLOW IN A ROW OF TUBES  FT**2             CON30700
CCCCC     AMWNC = MOLECULAR WEIGHT OF N/C GASSES                        CON30710
C         DELPC = PRESSURE DROP ACROSS COOLER                           CON30720
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C       DELPCT = PRESSURE LOSS AT COOLER DUE TO VELOCITY CHANGE          CON30730
C       DELTPC = PRESS DROP ACROSS A ROW OF TUBES  PSI                   CON30740
C       HEFFC = N/C GAS FILM HEAT TRANSFER COEF                          CON30750
C       HFG = STEAM LATENT HEAT OF VAPORIZATION  BTU/LBM                 CON30760
C       HTCLR = THE HEIGHT OF THE COOLER                                 CON30770
C       IHNOC = THE NUMBER OF HORIZONTAL TUBES IN THE COOLER             CON30780
C       IVNOC = THE NUMBER OF VERTICAL TUBES IN THE COOLER               CON30790
C       PAL = SAME AS PSAT                                               CON30800
C       PMIX1 = PRESS OF STM - N/C MIXTURE ENERING COND  PSIA            CON30810
C       PSATC = SATURATED STEAM PRESS                                    CON30820
C       PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE    CON30830
C         CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET          CON30840
C         COOLANT TEMPERATURE. THE RESULT IS 0 HEAT TRANSFER             CON30850
C       RCC = RATIO OF N/C GAS TO STM AT ONE ROW OF TUBES                CON30860
C       ROUTC = EXTERNAL HEAT TRANSFER COEF                              CON30870
C       SDDC = COOLER TUBE PITCH                                         CON30880
C       SDO = TUBE OD  FT                                                CON30890
C       SHIC = INTERNAL TUBE FILM HEAT TRANSFER COEF.                    CON30900
C       SHNFC = EXTERNAL TUBE FILM HEAT TRANSFER COEF                    CON30910
C       SMTBIC = ROW BY ROW SUM OF (COOLANT INLET TEMP * FLOW RATE)      CON30920
C       SMWBC = ROW BY ROW SUM OF COOLANT FLOW                           CON30930
C       SMTB2C = ROW BY ROW SUM OF (COOLANT OUTLET TEMP * FLOW RATE)     CON30940
C       SUMQC = ROW BY ROW SUM OF HEAT DUTY ON TUBES                     CON30950
C       SVMXEX = ENTERING MIXTURE SPECIFIC VOL  FT**3/LBM                CON30960
C       SVNCEX = ENTERING N/C GAS SPECIFIC VOL  FT**3/LBM                CON30970
C       STSATC = STAT STEAM TEMP AT A GIVEN ROW F                        CON30980
C       STSATC = STEAM SATURATION TEMP  F                                CON30990
C       STFO = AVE TEMP OF OUTER TUBE FILM                               CON31000
C       TAL = SATURATED STEAM TEMP  R                                    CON31010
C       TNOC = THE NUMBER OF TUBES IN THE COOLER                         CON31020
C       TSAREA = TUBE SHEET AREA                                         CON31030
C       UNC = OVERALL HEAT TRANSFER COEF FOR ONE ROW OF TUBES IN COOLER  CON31040
C       VG = SPECIFIC VOLUME OF STEAM FT**3/LB                           CON31050
C       VMIX = SPECIFIC VOLUME OF STEAM AND N/C GASSES IN MIXTURE        CON31060
C       VNREC = REYNOLDS NUMBER ON VAPOR SIDE AT A ROW IN COOLER         CON31070
C       VNC = SPECIFIC VOLUME OF N/C GAS FT**3/LB                        CON31080
C       VOLC = COOLER VOLUME                                             CON31090
C       VPSHHC = OUTLET COOLANT TEMP  F                                  CON31100
C       WCNDC = CONDENSATE FROM ONE ROW OF TUBES IN COOLER  LBM/HR       CON31110
C       WS = STEAM FLOW TO A ROW OF TUBES IN A SECTOR LB/HR              CON31120
C       WSC = STEAM FLOW TO A ROW OF COOLER  LBM/HR                      CON31130
C       WNCC = N/C FLOW TO A ROW OF COOLER  LBM/HR                       CON31140
C       WSEXIT = TOTAL STM FLOW TO COOLER LBM/HR                         CON31150
C                                                                        CON31160
      WNCC=WNCIR                                                         CON31170
      SDOC=ODII/12.                                                      CON31180
      SDO=SDOC                                                           CON31190
      SDDMIN=SDDC                                                        CON31200
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      TB2=TB2C                                                          CON31210
      AOC=PI*ALST*SDO                                                   CON31220
      AO=AOC                                                            CON31230
      WB=WBC                                                            CON31240
      FDAVE=0.5                                                         CON31250
      SDIC=SIC(NOROWS)                                                  CON31260
      SDI=SDIC                                                          CON31270
      AI=PI*ALST*SDI                                                    CON31280
      SHWINV=SHWINC                                                     CON31290
      ENHI=ENHIC                                                        CON31300
      ENHO=ENHOC                                                        CON31310
      ENHF=ENHFC                                                        CON31320
      STBIR=STBI+459.69                                                 CON31330
      PTLIM=PSATFN(STBIR)                                               CON31340
      SMTBIC=0.0                                                        CON31350
      SMWBC=0.0                                                         CON31360
      SMTB2C=0.0                                                        CON31370
      SUMQC=0.0                                                         CON31380
      WTSTC=0.                                                          CON31390
      IROWC=0                                                           CON31400
      WSOUT=0.                                                          CON31410
      SBFLOC=0.                                                         CON31420
      SBRATC=0.                                                         CON31430
      TBDRYC=0.                                                         CON31440
      AMLSCC=WNCC/AMWNC                                                 CON31450
      AXOC=SDC*HNOC*ALST*(SDOMIN-1.0)                                   CON31460
      SVGEXT=VGFN(TSATEX,PMXEXT)                                        CON31470
      SVNCEX=10.729*TSATEX/(AMWNC*(PMXEXT))                             CON31480
      AMLT=AMLSEX+AMLSCC                                                CON31490
      SVMXEX=1.0/(AMLSEX/(AMLT*SVGEXT)+AMLSCC/(AMLT*SVNCEX))            CON31500
      VELC(1)=(WSEXIT+WNCC)*SVMXEX/(AXOC*3600.0)                        CON31510
C                                                                       CON31520
      VLCMAX=VELC(1)                                                    CON31530
      G2=288.0*SG*SVMXEX                                                CON31540
      IF (VELC(1)-VELEXT) 10,10,20                                      CON31550
10    A2DA1=VELC(1)/VELEXT                                              CON31560
      DELPCT=((1.0-A2DA1)*VELEXT**2)/G2                                 CON31570
      GO TO 50                                                          CON31580
20    A2DA1=VELEXT/VELC(1)                                              CON31590
      IF (A2DA1-0.715) 40,40,30                                         CON31600
30    DELPCT=(0.75*(1.0-A2DA1)*VELC(1)**2)/G2                           CON31610
      GO TO 50                                                          CON31620
40    DELPCT=(0.4*(1.25-A2DA1)*VELC(1)**2)/G2                           CON31630
50    PMIXC(1)=PMXEXT-DELPCT-(VELC(1)**2-VELEXT**2)/G2                  CON31640
      PSATC(1)=PMIXC(1)*AMLSEX/(AMLSEX+AMLSCC)                          CON31650
C                                                                       CON31660
C     RECALCULATE THE AREA RATIO (THE RATIO OF TUBE X-SECTIONAL         CON31670
C     AREA TO TTUBE SHEET AREA) TO INCLUDE THE COOLER                   CON31680
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C                                                                       CON31690
      SECFLG=FLOAT(ISEC)                                                CON31700
      TSAREA=PI*(BNDRAD**2)*SECFLG*SECWID/360.                          CON31710
      AHOLES=ARATIO*TSAREA                                              CON31720
      AHOLES=AHOLES+(PI*SDO**2)*TNOC/4.                                 CON31730
      TSAREA=TSAREA+HTCLR*HNOC*SDOC*SDOC                                CON31740
      ARATIO=AHOLES/TSAREA                                              CON31750
C                                                                       CON31760
CC    CALCULATE THE CCOLER VOLUME                                       CON31770
C                                                                       CON31780
      VOLC=HTCLR*SDOC*SDOC*HNOC*ALST                                    CON31790
C                                                                       CON31800
CC    CHECK TO SEE IF INITIAL PRESSURE LOSSES DROP THE PRESSURE         CON31810
CC    BELOW PTLIM                                                       CON31820
C                                                                       CON31830
      IF (PSATC(1).GT.PTLIM) GO TO 80                                   CON31840
      SUMQC=0.                                                          CON31850
      NRWSP4=IVNOC+1                                                    CON31860
      CONS1A=PTLIM/FLOAT(NRWSP4)                                        CON31870
      CONS1B=PMXEXT/FLOAT(NRWSP4)                                       CON31880
      CUMDPC(1)=PMIX1-PMXEXT                                            CON31890
      PSATC(1)=PTLIM                                                    CON31900
      PMIXC(1)=PMXEXT                                                   CON31910
      QQAC(1)=0.                                                        CON31920
      DELPC=PMXEXT                                                      CON31930
      UNC(1)=700.                                                       CON31940
      WSC(1)=WSEXIT                                                     CON31950
      WCNDC(1)=0.                                                       CON31960
C                                                                       CON31970
      DO 60 M=2,NRWSP4                                                  CON31980
      WSC(M)=WSEXIT                                                     CON31990
      WCNDC(M)=0.                                                       CON32000
      PMIXC(M)=PMIXC(M-1)-CONS1B                                        CON32010
      PSATC(M)=PSATC(M-1)-CONS1A                                        CON32020
      CUMDPC(M)=PMIX1-PMIXC(M)                                          CON32030
60    CONTINUE                                                          CON32040
C                                                                       CON32050
      DO 70 M=2,IVNOC                                                   CON32060
      UNC(M)=700.                                                       CON32070
      QQAC(M)=0.                                                        CON32080
      ALMTDC(M)=0.                                                      CON32090
70    CONTINUE                                                          CON32100
      SMWBC=SMWBC+WB*TNOC                                               CON32110
      SMTBIC=WB*TNOC*STBI                                               CON32120
      SMTB2C=SMTBIC                                                     CON32130
      EXITFC=1.                                                         CON32140
      RETURN                                                            CON32150
C                                                                       CON32160
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80      PAL=PSATC(1)                                                    CON32170
        TAL=TSATFN(PAL)                                                 CON32180
        STSATC(1)=TAL-459.69                                            CON32190
        WSC(1)=WSEXIT                                                   CON32200
C                                                                       CON32210
CC    CHECK TO SEE IF INLET STEAM TO COOLER IS 0                        CON32220
C                                                                       CON32230
        IF (WSC(1).GT.1.) GO TO 90                                      CON32240
C                                                                       CON32250
CC    ENTER DUMMY VALUES IN COOLER VARIABLES                            CON32260
CC    CREATE NEGATIVE FLOW PARAMETER FOR USE IN COMPUTING EXITFRC       CON32270
C                                                                       CON32280
        TBDRYC=TNOC                                                     CON32290
        SBRATC=WCNDAV                                                   CON32300
        SBFLOC=SBRATC*TBDRYC                                            CON32310
C                                                                       CON32320
C                                                                       CON32330
        WSC(1)=1.                                                       CON32340
        IROWC=3                                                         CON32350
C                                                                       CON32360
90      VG=VGFN(TAL,PMIXC(1))                                           CON32370
        AMLSSC=WSC(1)/18.015                                            CON32380
        VNC=10.729*TAL/(AMWNC*PMIXC(1))                                 CON32390
        VMIX=1.0/((AMLSSC/(VG*(AMLSSC+AMLSCC)))+(AMLSCC/(VNC*(AMLSSC+AMLSC CON32400
       1C))))                                                           CON32410
        VELC(1)=(WSC(1)+WNCC)*VMIX/(AXOC*3600.0)                        CON32420
        NFC=(VNCC+1.)/2.0                                               CON32430
        ANFC=NFC                                                        CON32440
        IDT=0                                                           CON32450
        JRC=0                                                           CON32460
        IBT=0                                                           CON32470
        DO 450 IK=1,IVNOC                                               CON32480
        I=IK                                                            CON32490
        LJ=7                                                            CON32500
C                                                                       CON32510
CC      ROW BY ROW CALCULATION A LA HETTRN                              CON32520
C                                                                       CON32530
        STSAT=STSATC(I)                                                 CON32540
        ANF=ANFC                                                        CON32550
        WS=WSC(I)                                                       CON32560
        WNC=WNCC                                                        CON32570
        AXO=AXOC                                                        CON32580
        IR=I                                                            CON32590
C       DATA HEFF,UEST,DGFLM,DLFLM/2100.,700.,0.05,2.0/                 CON32600
C       DATA R2,E20K / 3.617,3.996,3.838,97.0,109.0,140.75/             CON32610
        DATA R2/3.617,3.996,3.838/                                      CON32620
        K=0                                                             CON32630
        RC=WNC/(WS+WNC)                                                 CON32640
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      TSAT=STSAT+459.69                                                          CON32650
      GMAX=(WS+WNC)/AXO                                                          CON32660
      PSAT=PSATFN(TSAT)                                                          CON32670
      AMOLSS=WS/18.015                                                           CON32680
      AMOLSC=WNC/AMWNC                                                           CON32690
      AMOLT=AMOLSS+AMOLSC                                                        CON32700
      AMWAV=(WS+WNC)/AMOLT                                                       CON32710
      RMWNC=SQRT(AMWNC)*AMOLSC/AMOLT                                             CON32720
      RMWSC=4.24444*AMOLSS/AMOLT                                                 CON32730
      AVIS=(SMUFN(TSAT)*RMWSC+AMUFN(TSAT,JGAS)*RMWNC)/(RMWSC+RMWNC)              CON32740
      HSTO=HFGFN(STSAT)                                                          CON32750
      BB=WB/(PI*SDI*SDI/4.)                                                      CON32760
      STBAVE=(STBI+TB2)/2.0                                                      CON32770
      DELFLM=DLFLM                                                               CON32780
      DLGFLM=DGFLM                                                               CON32790
      STWO=STSAT-DELFLM-DLGFLM                                                   CON32800
      STFO=(STSAT+STWO)/2.0                                                      CON32810
      XNRE=SDO*(WS+WNC)/(AXO*3600.*AVIS)                                         CON32820
      IF (XNRE.GE.100.) GO TO 100                                                CON32830
100   CONTINUE                                                                   CON32840
      COLBJ=EXP(0.53883-0.544*ALOG(XNRE))                                        CON32850
      IF (WNCIR.EQ.0.) GO TO 110                                                 CON32860
      PATM=PSAT/14.7                                                             CON32870
      PGB=PSAT*(AMOLSC/AMOLSS)                                                   CON32880
      TSATK=TSAT/1.8                                                             CON32890
      CALL DFSVTY (TSATK,PATM,18.015,AMWNC,2.655,R2(JGAS),363.,E2OK(JGASCON32900
     1),0.,0.,DG,DGG)                                                            CON32910
C****                                                                            CON32920
C  0.258 CONVERTS CM2/S TO FT2/HR AND 3600. CONVERTS VISCOSITY TO               CON32930
C  LB/F-HR FROM LB-F-S.          0.258 * 3600. = 928.8                          CON32940
C****                                                                            CON32950
      XNSCH=(AVIS*TSAT*10.73/((PSAT+PGB)*AMWAV*DG))*928.8                        CON32960
      CJ=COLBJ*GMAX/(XNSCH**0.666667)                                            CON32970
110   TB2=STSAT-(STSAT-STBI)/EXP(UEST*AO/(WB*CPFN(CBI,STBAVE)))                 CON32980
      STBAVE=(STBI+TB2)/2.                                                       CON32990
      SKBO=SKBFN(0.,STFO)                                                        CON33000
      SKB=SKBFN(CBI,STBAVE)                                                      CON33010
      BMU=BMUFN(CBI,STBAVE)                                                      CON33020
      SHBI=CPFN(CBI,STBAVE)                                                      CON33030
      XNREB=SDI*BB/BMU                                                           CON33040
      XNPRB=SHBI*BMU/SKB                                                         CON33050
      SHI=0.023*(XNREB)**0.8*XNPRB**0.33333*(SKB/SDI)*ENHI                       CON33060
      RIN=AO/(SHI*AI)                                                            CON33070
      BNF=ANF                                                                    CON33080
      IF (ANF.LE.1.0) BNF=1.0                                                    CON33090
      SHMK=0.725*(SKBO**3*ROEFN(0.0,STFO)**2*HFGFN(STFO)*416975040.0/(BMCON33100
     1UFN(0,STFO)*SDO*DELFLM))**.25*ENHO                                         CON33110
C                                                                                CON33120
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C THIS IS THE PLACE TO ENTER CORRECTIONS TO EXTERNAL FILM COEFFICIENT    CON33130
C FOLLOWING IS A CORRECTION ACCORDING TO FUJII, ET. AL. TO ACCOUNT FOR  CON33140
C EFFECTS OF VAPOR SHEAR AT HIGH VAPOR REYNOLDS NUMBERS                 CON33150
C                                                                       CON33160
      SHMK1=SHMK                                                        CON33170
      ANUS=SHMK*SDO/SKBO                                                CON33180
      EMUL=BMUFN(0.,STSAT)                                              CON33190
      EMUS=SMUFN(TSAT)*3600.                                            CON33200
      RHOL=RCEFN(0.,STSAT)                                              CON33210
      RHOS=1./VGFN(TSAT,PSAT)                                           CON33220
      VISRAT=(EMUS/RHOS)/(EMUL/RHOL)                                    CON33230
      RETP=XNRE*VISRAT                                                  CON33240
C                                                                       CON33250
      IF (RETP.LT.0.) RETP=0.                                           CON33260
      IF (RETP.LT.0.) GO TO 120                                         CON33270
C                                                                       CON33280
120   TERM=SQRT(RETP)/ANUS                                              CON33290
      IF (TERM.LT..278) GO TO 130                                       CON33300
      ANUSP=1.24*(ANUS**0.8)*(RETP**0.1)                                CON33310
      GO TO 140                                                         CON33320
130   ANUSP=ANUS*0.70/0.725                                             CON33330
140   SHMKP=ANUSP*SKBC/SDO                                              CON33340
      SHMK=SHMKP                                                        CON33350
C                                                                       CON33360
CCC####################################################################CON33370
CC#                                                                   #CON33380
CC#         IF HO > 40,000                                            #CON33390
CC#                                                                   #CON33400
CC#                                                                   #CON33410
CC#####################################################################CON33420
CCC   IF (SHMK .GT. 40000.)  GO TO 49                                   CON33430
CCC   IF (SHMK.LT.40000..AND.DELFLM.GT..0001) GO TO 49                  CON33440
CCC 49 CONTINUE                                                         CON33450
CCCCC                                                                   CON33460
CCCCC  INUNDATION EFFECT MAY BE BYPASSED BY SETTING BNF = 1.            CON33470
C                                                                       CON33480
C     BNF = 1.                                                          CON33490
      IF (FDAVE.LT.0..OR.BNF.LT.2.) GO TO 150                           CON33500
      FDAVN=0.6*FDAVE+(1.-0.5647*FDAVE)/BNF**.20                        CON33510
      FDAVM=0.6*FDAVE+(1.-0.5647*FDAVE)/(BNF-1)**.20                    CON33520
      SHNF=SHMK*(BNF*FDAVN-(BNF-1.)*FDAVM)                              CON33530
      GO TO 160                                                         CON33540
150   SHNF=0.95*(BNF**0.9-(BNF-1.)**0.9)*SHMK                           CON33550
C                                                                       CON33560
160   RFACT=RIN+SHWINV+FOUL+1./SHNF                                     CON33570
C                                                                       CON33580
C     COMPUTE LOG MEAN DELTA TEMP., ALMTD                               CON33590
C                                                                       CON33600
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C*****                                                                  CON33610
      HOMCI=STSAT-STBI                                                  CON33620
      HIMCO=STSAT-TB2                                                   CON33630
C                                                                       CON33640
C     IF (HIMCO.LT.1.E-15) WRITE (6,530) HOMCI,HIMCO,LJ,IR              CON33650
      IF (HIMCO.LT.1.E-15) HIMCO=1.E-15                                 CON33660
C                                                                       CON33670
      RODT=HOMCI/HIMCO                                                  CON33680
C                                                                       CON33690
C     IF INLET/OUTLET DELTA T RATIO IS NEAR 1.0, ALMTD = ARITH AVE      CON33700
      IF (RODT.GT.1.1) GO TO 170                                        CON33710
      ALMTD=0.5*(HOMCI+HIMCO)                                           CON33720
C     IF (JRC.EQ.0) WRITE (6,540) STSAT,STBI,TB2,LJ,IR                  CON33730
      JRC=1                                                             CON33740
      GO TO 180                                                         CON33750
170   ALMTD=(HOMCI-HIMCO)/ALOG(RODT)                                    CON33760
180   CONTINUE                                                          CON33770
      IF (WNCIR.NE.0.) GO TO 190                                        CON33780
      ROUT=1./SHNF                                                      CON33790
      UTEST=1./RFACT                                                    CON33800
      XNU=SHNF*SDO/SKBO                                                 CON33810
      IF (ABS(UEST-UTEST)/UTEST.LT..001) GO TO 280                      CON33820
      UESTSV=UEST                                                       CON33830
      UEST=UTEST                                                        CON33840
      IF (K.GT.4) UEST=0.5*(UTEST+UESTSV)                               CON33850
      STWO=STSAT-(STSAT-STBAVE)*UTEST/SHNF                              CON33860
      STCO=STSAT                                                        CON33870
      STFO=(STCO+STWO)/2.                                               CON33880
      DGFLM=0.                                                          CON33890
      DLFLM=STCO-STWO                                                   CON33900
      DELFLM=DLFLM                                                      CON33910
      K=K+1                                                             CON33920
      IF (K.LT.20) GO TO 110                                            CON33930
      WRITE (6,510) UESTSV,UTEST                                        CON33940
      GO TO 280                                                         CON33950
190   CONTINUE                                                          CON33960
      STCO=STSAT-DLGFLM                                                 CON33970
      T=(TSAT+STCO+459.69)/2.0                                          CON33980
      DTDP=1./(((6452.562+2.*837533.2/T)/T**2)*EXP(14.15012-(6452.562+83CON33990
     1 7533.2/T)/T))                                                    CON34000
      BONE=-1.*(CJ*HSTO/ALMTD+(PGB*DTDP/ALMTD+1.)/RFACT)                CON34010
      CONE=CJ*HSTO/(ALMTD*RFACT)                                        CON34020
      TTERM1=BONE**2                                                    CON34030
      TTERM2=4.*CONE                                                    CON34040
      TTERM=TTERM2/TTERM1                                               CON34050
      IF (TTERM.LT.0.999999) GO TO 200                                  CON34060
      UTEST=-BONE/2.                                                    CON34070
      GO TO 220                                                         CON34080
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200   IF ((4.*CONE).GT.(BONE**2)) UTEST=0.                              CON34090
      IF ((4.*CONE).GT.(BONE**2)) GO TO 210                             CON34100
      UTEST=(-SQRT(BONE**2-4.*CONE)-BONE)/2.                            CON34110
210   DENOM=1.-UTEST*RFACT                                              CON34120
220   CONTINUE                                                          CON34130
      IF (DENOM.GT.1.E-7) GO TO 230                                     CON34140
      HEFF=1.0E8                                                        CON34150
      GO TO 240                                                         CON34160
230   HEFF=UTEST/DENOM                                                  CON34170
240   CONTINUE                                                          CON34180
      ROUT=(HEFF+SHNF)/(HEFF*SHNF)                                      CON34190
      TDIF=STSAT-STBAVE                                                 CON34200
      IF (TDIF.GT.0) GO TO 250                                          CON34210
      IF (IBT.EQ.0) WRITE (6,530) STSAT,STBAVE,LJ,IR                    CON34220
      IBT=1                                                             CON34230
      TDIF=.1                                                           CON34240
250   CONTINUE                                                          CON34250
      DELTAU=TDIF*UTEST                                                 CON34260
      DGFLM=DELTAU/HEFF                                                 CON34270
      DLFLM=DELTAU/SHNF                                                 CON34280
      STCO=STSAT-DGFLM                                                  CON34290
      STWO=STCO-DLFLM                                                   CON34300
      STFO=(STCO+STWO)/2.                                               CON34310
      XNU=SDO/(SKBO*ROUT)                                               CON34320
      IF (ABS(UTEST-UEST)/UTEST.LT..001) GO TO 260                      CON34330
      DELFLM=DLFLM                                                      CON34340
      DLGFLM=DGFLM                                                      CON34350
      UESTSV=UEST                                                       CON34360
      UEST=UTEST                                                        CON34370
      K=K+1                                                             CON34380
      IF (K.GT.4) UEST=0.5*(UTEST+UESTSV)                               CON34390
      IF (K.LT.20) GO TO 110                                            CON34400
      WRITE (6,510) UESTSV,UTEST                                        CON34410
      GO TO 280                                                         CON34420
260   IF (ABS(DELFLM-DLFLM).LT..01) GO TO 270                           CON34430
      DELFLM=DLFLM                                                      CON34440
      DLGFLM=DGFLM                                                      CON34450
      K=K+1                                                             CON34460
      IF (K.LT.20) GO TO 110                                            CON34470
      WRITE (6,520) DELFLM,LJ,IR                                        CON34480
270   IF (ABS(DLGFLM-DGFLM).LT..001) GO TO 280                          CON34490
      DLGFLM=DGFLM                                                      CON34500
      K=K+1                                                             CON34510
      IF (K.LT.20) GO TO 110                                            CON34520
      WRITE (6,500) DLGFLM,UEST,UTEST,LJ,IR                             CON34530
280   VNF=UTEST                                                         CON34540
      VPSHH=TB2                                                         CON34550
      XHEFF=HEFF                                                        CON34560
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      ROUT=1./ROUT                                                          CON34570
      UNC(I)=VNF                                                            CON34580
      ALMTDC(I)=ALMTD                                                       CON34590
      SHIC(I)=SHI                                                           CON34600
      SHNFC(I)=SHNF                                                         CON34610
      RCC(I)=RC                                                             CON34620
      ROUTC(I)=ROUT                                                         CON34630
      VNREC(I)=XNRE                                                         CON34640
      VPSHHC(I)=VPSHH                                                       CON34650
      HEFFC(I)=SHEFF                                                        CON34660
C                                                                           CON34670
CCC   COMPLETICN OF TUBE H/T CALCULATION                                    CON34680
C                                                                           CON34690
      HFG=HFGFN(STSATC(I))                                                  CON34700
      WCNDC(I)=UNC(I)*AO*HNOC*ALMTDC(I)/HSTO                                CON34710
      CALL PRSDRP (TAL,VMIX,WSC(I),WNCC,AXOC,SDO,VPSHC(I),DELTPC,ENHF)      CON34720
      JY=0                                                                  CON34730
290   WSC(I+1)=WSC(I)-WCNDC(I)                                              CON34740
      GFLOWC(I)=(WSC(I)+WNCC)/AXOC                                          CON34750
C                                                                           CON34760
CCC   CHECK FOR NEGATIVE STEAM FLOW                                         CON34770
C                                                                           CON34780
      IF (WSC(I+1)-1) 300,300,360                                           CON34790
C                                                                           CON34800
CCC   IF PREVIOUS COND. RATE PREDICTS STEAM FLOW WILL GO NEG AFTER THE      CON34810
CCCC  NEXT ROW, SET CONDENSATE EQUAL TO STEAM FLOW.                         CON34820
C                                                                           CON34830
300   WCNDC(I)=WSC(I)                                                       CON34840
C                                                                           CON34850
CCC   IF STEAM FLOW HAS ALREADY GONE NEGATIVE THEN AVOID CALCULATING        CON34860
CCCC  TEST VARIABLE                                                         CON34870
C                                                                           CON34880
      IF (IROWC.GT.0) GO TO 310                                             CON34890
C                                                                           CON34900
CCC   CREATE A TEST VARIABLE INDICATING POINT IN COOLER WHERE STEAM         CON34910
CCC   BAD AND A NEGATIVE FLOW RATE FOR USE IN CALCULATING EXITFRC           CON34920
C                                                                           CON34930
      WTSTC=(WSC(I+1)-1.)/(WSC(I)-WSC(I+1)+1.)                              CON34940
      WTSTC=WTSTC-FLOAT(IVNOC-I)                                            CON34950
      IROWC=1                                                               CON34960
C                                                                           CON34970
      NRODRY=IVNOC-I                                                        CON34980
      TBDRYC=TNOC*(FLOAT(NRODRY)/FLOAT(IVNOC))                              CON34990
      TBDRYC=TBDRYC-WTSTC*HNOC                                              CON35000
      SBRATC=WCNDC(I)/HNOC                                                  CON35010
      SBFLOC=SBRATC*TBDRYC                                                  CON35020
C                                                                           CON35030
C                                                                           CON35040
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310   STSATC(I+1)=STFG                                                      CON35050
      TSATMN=STSATC(I+1)+459.69                                             CON35060
      PMIN=PSATFN(TSATMN)                                                   CON35070
C                                                                           CON35080
C     ENTER DUMMY VALUE FOR NEXT ROW WSC                                    CON35090
C                                                                           CON35100
      WSC(I+1)=1.                                                           CON35110
C                                                                           CON35120
      QGC=(WSC(I)*CPSFN(TAL)/18.015+WNCC*CPAFN(TAL,JGAS)/AMWNC)*(TAL-TSACON35130
     1TMN)                                                                  CON35140
      QTC=QGC+QCNDC(I)*HFG                                                  CON35150
      IF (STSATC(I)-TB2) 320,320,330                                        CON35160
320   TB2=STSATC(I)-0.1                                                     CON35170
330   CONTINUE                                                              CON35180
      IF (STSATC(I+1).GT.STBI) GO TO 340                                    CON35190
      ALMTDC(I)=ALMTDC(I-1)                                                 CON35200
      GO TO 350                                                             CON35210
340   CONTINUE                                                              CON35220
      ALMTDC(I)=((STSATC(I+1)-STBI)-(STSATC(I)-TB2))/ALOG((STSATC(I+1)-SCON35230
     1TBI)/(STSATC(I)-TB2))                                                 CON35240
350   CONTINUE                                                              CON35250
      UNC(I)=QTC/(AO*HNOC*ALMTDC(I))                                        CON35260
      AMLSSC=WSC(I+1)/18.015                                                CON35270
      PMIXC(I+1)=PMIXC(I)-DELTPC                                            CON35280
      PSATC(I+1)=(PMIXC(I+1)*AMLSSC)/(AMLSSC+AMLSCC)                        CON35290
      TSATC=TSATMN                                                          CON35300
      GO TO 440                                                             CON35310
C                                                                           CON35320
CC                                                                          CON35330
360   AMLSSC=WSC(I+1)/18.015                                                CON35340
      PMIXC(I+1)=PMIXC(I)-DELTPC                                            CON35350
      PSATC(I+1)=(PMIXC(I+1)*AMLSSC)/(AMLSSC+AMLSCC)                        CON35360
C                                                                           CON35370
CC    CHECK TO SEE IF STEAM CORRECTIONS FOR DRY TUBES DROVE PSATC TOO LOCON35380
C                                                                           CON35390
      IF ((IROWC.GT.0).AND.(PSATC(I+1).LE.PTLIM)) WRITE (6,560) I           CON35400
      IF ((IROWC.GT.0).AND.(PSATC(I+1).LE.PTLIM)) PSATC(I+1)=PSATC(I)       CON35410
C                                                                           CON35420
CC    CHECK FOR PRESSURE DROPPING BELOW PTLIM                               CON35430
C                                                                           CON35440
      IF (PSATC(I+1).GT.PTLIM) GO TO 390                                    CON35450
C                                                                           CON35460
CC    CALCULATE PARAMETERS FOR CURRENT ROW                                  CON35470
C                                                                           CON35480
      PSATC(I)=PTLIM                                                        CON35490
      CUMDPC(I)=PMIX1-PMIXC(I)                                              CON35500
      SUMQC=SUMQC+UNC(I)*AO*ALMTDC(I)*HNOC                                  CON35510
      QDAC(I)=UNC(I)*ALMTDC(I)                                              CON35520
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      SMWBC=SMWBO+WB*HNOC                                                    CON35530
      SMTBIC=SMTBIC+WB*HNOC*STBI                                             CON35540
      SMTB2C=SMTB2C+WB*HNOC*TB2                                              CON35550
C                                                                            CON35560
      NRWSP4=IVNOC+1                                                         CON35570
      RTG=FLOAT(NRWSP4-1)                                                    CON35580
      NRWSP5=I+1                                                             CON35590
      CONST=PMIXC(I)/RTG                                                     CON35600
      CONST2=PTLIM/RTG                                                       CON35610
C                                                                            CON35620
CC    CALCULATE PARAMETERS FOR THE REMAINING ROWS                            CON35630
C                                                                            CON35640
      DO 370 M=NRWSP5,NRWSP4                                                 CON35650
      QQAC(M)=0.                                                             CON35660
      WSC(M)=WSC(M-1)                                                        CON35670
      WCNDC(M)=0.                                                            CON35680
      STSATC(M)=STSATC(M-1)                                                  CON35690
      PSATC(M)=PSATC(M-1)-CONST2                                             CON35700
      PMIXC(M)=PMIXC(M-1)-CONST                                              CON35710
      VELC(M)=VELC(M-1)                                                      CON35720
370   CONTINUE                                                               CON35730
C                                                                            CON35740
      DO 380 IFX=NRWSP5,IVNOC                                                CON35750
      UNC(IFX)=UNC(IFX-1)                                                    CON35760
      CUMDPC(IFX)=PMIX1-PMIXC(IFX-1)                                         CON35770
      SMTBIC=SMTBIC+WB*HNOC*STBI                                             CON35780
      SMTB2C=SMTBIC                                                          CON35790
      QQAC(IFX)=0.                                                           CON35800
      SMWBC=SMWBC+WB*HNOC                                                    CON35810
380   ALMTDC(IFX)=0.                                                         CON35820
C                                                                            CON35830
      DELPC=PMIXC(1)-PMIXC(NRWSP4)                                           CON35840
C                                                                            CON35850
      GO TO 460                                                              CON35860
C                                                                            CON35870
390   PAL=PSATC(I+1)                                                         CON35680
      IF (PAL.GT.0.) GO TO 400                                               CON35890
      WRITE (6,550) PMIXC(I),I                                               CON35900
400   CONTINUE                                                               CON35910
      TSATC=TSATFN(PAL)                                                      CON35920
      STSATC(I+1)=TSATC-459.69                                               CON35930
      IF (ABS(TSATC-TAL).LT.0.001) TSATC=TAL-0.001                           CON35940
      WCNDP=(UNC(I)*AO*HNOC*ALMTDC(I)-(WSC(I)*CPSFN(TSATC)/18.015+WNCC*C     CON35950
     1PAFN(TSATC,JGAS)/AMWNC)*(TAL-TSATC))/HFG                               CON35960
      IF (ABS(WCNDP/WCNDC(I)-1.0)-.005) 430,410,410                          CON35970
410   WCNDC(I)=WCNDP                                                         CON35980
      JY=JY+1                                                                CON35990
      IF (JY-50) 290,290,420                                                 CON36000
```

```
  420   WRITE (6,540) I                                                    CON36010
  430   CONTINUE                                                           CON36020
        WCNDC(I)=WCNDP                                                     CON36030
        WSC(I+1)=WSC(I)-WCNDC(I)                                           CON36040
        AMLSSC=WSC(I+1)/18.015                                             CON36050
        PSATC(I+1)=(PMIXC(I+1)*AMLSSC)/(AMLSSC+AMLSCC)                     CON36060
        PAL=PSATC(I+1)                                                     CON36070
        TSATC=TSATFN(PAL)                                                  CON36080
        STSATC(I+1)=TSATC-459.69                                           CON36090
  440   VG=VGFN(TSATC,PMIXC(I+1))                                          CON36100
        VNC=10.729*TSATC/(AMWNC*PMIXC(I+1))                                CON36110
        VMIX=1.0/((AMLSSC/(VG*(AMLSSC+AMLSCC)))+(AMLSCC/(VNC*(AMLSSC+AMLSC CON36120
       1C))))                                                              CON36130
        VELC(I+1)=(WSC(I+1)+WNCC)*VMIX/(AXOC*3600.0)                       CON36140
        SMTBIC=SMTBIC+WB*HNOC*STBI                                         CON36150
        SMWBC=SMWBO+WB*HNOC                                                CON36160
        SMTB2C=SMTB2C+WB*HNOC*TB2                                          CON36170
        SUMOC=SUMOC+UNC(I)*AO*ALMTDC(I)*HNOC                               CON36180
        GOAC(I)=UNC(I)*ALMTDC(I)                                           CON36190
        CUMDPC(I)=PMIX1-PMIXC(I)                                           CON36200
        TAL=TSATC                                                          CON36210
        ANFC=ANFC-1.0                                                      CON36220
  450   CONTINUE                                                           CON36230
        DELPC=PMIXC(1)-PMIXC(IVNOC+1)                                      CON36240
  460   CONTINUE                                                           CON36250
C                                                                          CON36260
CC      CHECK TO SEE IF INLET STEAM FLOW WAS 0                             CON36270
C                                                                          CON36280
        IF (IROWC.LT.2) GO TO 480                                          CON36290
        NRWSP4=IVNOC+1                                                     CON36300
        SUMOC=0.                                                           CON36310
        DO 470 M=1,NRWSP4                                                  CON36320
        GOAC(M)=0.                                                         CON36330
        ALMTDC(M)=0.                                                       CON36340
        WSC(M)=0.                                                          CON36350
  470   WCNDC(M)=0.                                                        CON36360
        EXITFC=-999                                                        CON36370
        WTSTC=FLOAT(IVNOC)                                                 CON36380
        RETURN                                                             CON36390
C                                                                          CON36400
CC      IF COOLER TUBES WENT DRY CREATING A NEGATIVE EXITFC                CON36410
C                                                                          CON36420
  480   IF (WTSTC.GE.0.) GO TO 490                                         CON36430
        EXITFC=-(SBFLDC)/WSC(1)                                            CON36440
        RETURN                                                             CON36450
C                                                                          CON36460
  490   EXITFC=WSC(I+1)/WSC(1)                                             CON36470
        WSOUT=WSC(I+1)                                                     CON36480
```

```
C                                                                       CON36490
      RETURN                                                            CON36500
C                                                                       CON36510
500   FORMAT (1HO,36H NO CONVERGENCE IN FILM TEMPERATURES,8H DLGFLM=,E12CON36520
     1.5,7H UEST =,E12.5,8H UTEST =,E12.5/10H SECTOR = ,I5,5H ROW=,I5)  CON36530
510   FORMAT (1HO,32H NO CONVERGENCE IN UESY, UEST = ,E12.5,9H UTEST = ,CON36540
     1E12.5)                                                            CON36550
520   FORMAT (1HO,34H NO CONVERGENCE IN DELFLM, DELFLM=,E12.5,8H SECTOR=CON36560
     1,I5,5H ROW=,I5)                                                   CON36570
530   FORMAT (1HO,53H  SAT STEAM TEMP LESS THAN AVG BRINE TEMP,    STSATCON36580
     1 =,E12.5,10H STBAVE =  ,E12.5,9H   SECTOR,I3,6H   ROW,I4)         CON36590
540   FORMAT (1HO,25HNO CONVERGENCE FOR WCNDC(,I2,2H).)                 CON36600
550   FORMAT (1HO,68H**** SATURATED STEAM PRESSURE IN COOLER HAS GONE NECON36610
     1GATIVE,   PMIXC =,E15.5,6H   ROW,I5)                              CON36620
560   FORMAT (1X,52HERROR,COOLER PTLIM VIOLATED DUE TO STEAM CORRECTIONSCON36630
     1/1X,41HFOR NEGATIVE FLOW. PTLIM VIOLATED IN ROW ,I5/)             CON36640
      END                                                               CON36650
C                                                                       CON36660
C***********************************************************************CON36670
C***********************************************************************CON36680
C                                                                       CON36690
      SUBROUTINE OUT2                                                   CON36700
C-------------                                                          CON36710
C OUT2 1                                                                CON36720
C                     SUMMARY OUTPUT                                    CON36730
C ZZZ OUT2                                                              CON36740
C-------------                                                          CON36750
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,CON36760
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNOTOCON36770
     2T,BNDRAD,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCLR                       CON36780
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON36790
     1TSATI,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON36800
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON36810
     3,WSI,PFILL                                                        CON36820
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMOUT(10CON36830
     10)                                                                CON36840
      COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)                          CON36850
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNC,VEL2,FR              CON36860
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,ACC,SUMQC,SDIC,SDOC,UBARW,SMWBC,CON36870
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AOT,BUNWT,AVTBI,AVTB2,WTSTC,VOLC CON36880
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST                         CON36890
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEFCON36900
     1F(100,15),PMIX(100,15),PSAT(100,15),QQA(100,15),RC(100,15),ROUT(10CON36910
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)CON36920
     3,VNRE(100,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WSI(100,15CON36930
     4),WSP(15)                                                         CON36940
      COMMON /COOL1/ VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100CON36950
     11),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),CON36960
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     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QOAC(100),C CON36970
     3UMDPC(100)                                                        CON36980
      COMMON /COOL/ IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,T CON36990
     1B2C,ENHIC,ENHOC,ENHFC,SHWINC,WBC                                  CON37000
      COMMON /OUT2A/ RCORR,RSPF,PHPCON,VOL1C                            CON37010
      DIMENSION AWTST(15)                                               CON37020
      DELPVE=0.                                                         CON37030
      AOT=0.                                                            CON37040
      VEL3=0.                                                           CON37050
      CAWT=0.                                                           CON37060
      UBARW=0.                                                          CON37070
      VWBAR=0.                                                          CON37080
      SECFLG=FLOAT(ISEC)                                                CON37090
      DO 10 I=1,NOROWS                                                  CON37100
      OD=ODOI-DELOD*FLOAT(I-1)                                          CON37110
      CAWT=CAWT+(OD*OD/144.-SID(I)*SID(I))*TBNPR(I)                     CON37120
      AO=3.14159*OD*ALST*TBNPR(I)/12.                                   CON37130
      VWBAR=VWBAR+VW(I)                                                 CON37140
   10 AOT=AOT+AO                                                        CON37150
      BUNWT=PI*CAWT*ALST*TUBESW*SECFLG/4.                               CON37160
      AOT=AOT*SECFLG                                                    CON37170
      DO 30 J=1,ISEC                                                    CON37180
      DO 20 I=1,NOROWS                                                  CON37190
   20 UBARW=UBARW+UN(I,J)*TBNPR(I)                                      CON37200
      VEL3=VEL3+VEL(NOROWS,J)                                           CON37210
      DELPVE=DELPVE+DELP(J)                                             CON37220
   30 CONTINUE                                                          CON37230
      UBARW=UBARW/TNO                                                   CON37240
      VWBAR=VWBAR/FLOAT(NOROWS)                                         CON37250
      VEL3=VEL3/SECFLG                                                  CON37260
      DELPVE=DELPVE/SECFLG                                              CON37270
      ADTCND=SUMQ/(UBARW*AOT)                                           CON37280
      STSATX=TSATEX-459.69                                              CON37290
      TDROP1=STSAT(1,1)-STSATX                                          CON37300
C                                                                       CON37310
      RSPI=RSPF*12.                                                     CON37320
C                                                                       CON37330
      BNDIAM=BNDRAD*2.                                                  CON37340
      BL=ALST/2.                                                        CON37350
      VOIDID=RADINS*2.                                                  CON37360
      AVTB1=SMTB1/SMWB                                                  CON37370
      AVTB2=SMTB2/SMWB                                                  CON37380
      HDLOSS=DELWP*144./62.366                                          CON37390
C                                                                       CON37400
C     THERE IS THE POSSIBILITY THAT THE AVERAGE INLET COOLANT TEMP      CON37410
C     (AVTB1) EQUALS THE AVERAGE OUTLET COOLANT TEMP (AVTB2). WHEN      CON37420
C     THE CONDENSER IS CONNFIGURED SUCH THAT NO HEAT IS REMOVED FROM    CON37430
C     THE STEAM                                                         CON37440
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      C                                                                      CON37450
            IF (AVTB1.EQ.AVTB2) DTCND2=0.                                    CON37460
            IF (AVTB1.EQ.AVTB2) UPCOND=UBARW                                 CON37470
            IF (AVTB1.EQ.AVTB2) GO TO 40                                     CON37480
      C                                                                      CON37490
            DTCND2=(AVTB2-AVTB1)/ALOG((STSAT1-AVTB1)/(STSAT1-AVTB2))         CON37500
            UPCOND=SUMQ/(AOT*DTCND2)                                         CON37510
      40    WRITE (6,60)                                                     CON37520
            WRITE (6,80)                                                     CON37530
            WRITE (6,90)                                                     CON37540
            WRITE (6,100)                                                    CON37550
            WRITE (6,90)                                                     CON37560
            WRITE (6,80)                                                     CON37570
            WRITE (6,70)                                                     CON37580
            WRITE (6,110) UBARW,ADTCND,DELPVE,TDROP1,VEL2,VEL3               CON37590
            WRITE (6,120) SUMQ                                               CON37600
            WRITE (6,130) WSI                                                CON37610
            WRITE (6,160) AOT                                                CON37620
            WRITE (6,140) EXITFR                                             CON37630
      C                                                                      CON37640
            DO 50 I=1,ISEC                                                   CON37650
            IF (WTST(I).LT.0.) AWTST(I)=-WTST(I)                             CON37660
            IF (WTST(I).LT.0.) WRITE (6,150) I,AWTST(I)                      CON37670
  211   50  CONTINUE                                                         CON37680
      C                                                                      CON37690
            WRITE (6,170) TNQ,NOROWS                                         CON37700
            WRITE (6,180) ALST                                               CON37710
            WRITE (6,190) VOIDID,BNDIAM,BL                                   CON37720
            IF (MDIAM.EQ.1) WRITE (6,200) SIDO,ODOI                          CON37730
            IF (MDIAM.EQ.2) WRITE (6,210) SIDI,ODII                          CON37740
            IF (MDIAM.EQ.2) WRITE (6,220) SIDO,ODOI                          CON37750
            IF (MPITCH.EQ.1) WRITE (6,230) SDDO                              CON37760
            IF (MPITCH.EQ.2) WRITE (6,240) SDDI,SDDO                         CON37770
            IF (XW2.GT.0.) WRITE (6,250) XW2                                 CON37780
            IF (XW2.LE.0.) WRITE (6,260) XW1                                 CON37790
            WRITE (6,270) RSPI                                               CON37800
            WRITE (6,280) VCLIC,VOL2,BUNWT                                   CON37810
            WRITE (6,290) AVTB1                                              CON37820
            WRITE (6,300) AVTB2                                              CON37830
            WRITE (6,320) SMWB                                               CON37840
            WRITE (6,330) VWBAR                                              CON37850
            WRITE (6,310) HDLOSS,PHPCON                                      CON37860
            WRITE (6,340) DTCND2                                             CON37870
            WRITE (6,350) UPCOND                                             CON37880
            WRITE (6,360) PFILL                                              CON37890
            IF (PRCCLR.LE.0) WRITE (6,370) ARATIO                            CON37900
            IF (PRCCLR.GT.0.) CALL OUT2C                                     CON37910
            RETURN                                                           CON37920
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60    FORMAT (1H1)                                                          CON37930
70    FORMAT (1H0,31X,29H********  CONDENSER  ********//)                   CON37940
80    FORMAT (1H ,15X,16X,29H*****************************)                CON37950
90    FORMAT (1H ,15X,16X,1H*,27X,1H*)                                      CON37960
100   FORMAT (1H ,15X,16X,29H* CONDIP SUMMARY OF RESULTS *)                 CON37970
110   FORMAT (1H ,10X,56HOVERALL U   LOG-MEAN  PRESSURE    TEMP.    STEAMCON37980
     1 VELOCITY/10X,54HB/HR-DEG.F  DELTA T    DROP       DROP          FCON37990
     2T/SEC/11X,57H-SQ.FT.    DEG.F       PSIA       DEG.F      INLET    OUCON38000
     3TLET//12X,F6.2,3X,F6.2,4X,1PE9.2,1P3E10.2/)                          CON38010
120   FORMAT (1H ,10X,12HHEAT DUTY    ,8X,1PE11.4,2X,6HBTU/HR)              CON38020
130   FORMAT (1H ,10X,18HSTEAM TO BUNDLE    ,2X,1PE11.4,2X,5HLB/HR)         CON38030
140   FORMAT (1H ,10X,13HEXIT FRAC.    ,7X,1PE11.4/)                        CON38040
150   FORMAT (1H ,10X,10HIN SECTOR ,I2,2X,29HTHE FRACTION OF DRY ROWS WACON38050
     1S ,F10.6)                                                            CON38060
160   FORMAT (1H ,10X,19HHT. TRF. SURF. AREA,1X,1PE11.4,2X,6HSQ.FT.)        CON38070
170   FORMAT (1H ,1X/10X,16HBUNDLE DIAMETER,,3X,2HFT,7X,F10.2,1X,6HTUBESCON38080
     1,,I5,1X,4HROWS)                                                      CON38090
180   FORMAT (1H ,12X,6HINSIDE,4X,7HOUTSIDE,13X,10HTUBES ARE ,F5.2,1X,7HCON38100
     1FT LONG)                                                             CON38110
190   FORMAT (1H ,12X,F5.2,5X,F5.2,14X,11HBUNDLE IS  ,F5.2,1X,7HFT LONG/CON38120
     1)                                                                    CON38130
200   FORMAT (1H ,10X,20HTUBE INSIDE DIAMETER,15X,F7.4,2X,6HINCHES/1H ,1CON38140
     10X,21HTUBE OUTSIDE DIAMETER,14X,F7.4,2X,6HINCHES)                    CON38150
210   FORMAT (1H ,10X,30HTUBE INSIDE DIAMETER INNER ROW,6X,F7.4,2X,3HIN.CON38160
     1/11X,31HTUBE OUTSIDE DIAMETER INNER ROW,5X,F7.4,2X,3HIN./)           CON38170
220   FORMAT (1H ,11X,30HTUBE INSIDE DIAMETER OUTER ROW,5X,F7.4,2X,3HIN.CON38180
     1/11X,31HTUBE OUTSIDE DIAMETER OUTER ROW,5X,F7.4,2X,3HIN.)            CON38190
230   FORMAT (1H ,10X,26HTUBE CIRCUMFERENTIAL PITCH,9X,F7.4)                CON38200
240   FORMAT (1H ,10X,36HTUBE CIRCUMFERENTIAL PITCH INNER ROW,5X,F7.4/1HCON38210
     1 ,10X,36HTUBE CIRCUMFERENTIAL PITCH OUTER ROW,5X,F7.4)               CON38220
250   FORMAT (1H ,10X,14HTUBE THICKNESS,21X,F7.4,2X,6HINCHES)               CON38230
260   FORMAT (1H ,10X,34HRATIO OF TUBE THICKNESS TO TUBE OD,5X,F7.4)        CON38240
270   FORMAT (1H ,10X,28HSPACE BETWEEN COCENTRIC ROWS,7X,F7.4,2X,3HIN./)CON38250
280   FORMAT (1H ,10X,13HBUNDLE VOLUME,7X,1PE11.4,2X,6HCU.FT./11X,19HTUBCON38260
     1E SPACE VOLUME   ,1X,1PE11.4,2X,6HCU.FT./11X,19HTUBE METAL WEIGHT  CON38270
     2,1X,1PE11.4,2X,2HLB/)                                                CON38280
290   FORMAT (1H ,10X,19HINLET WATER TEMP    ,5X,F9.2,1X,5HDEG.F)           CON38290
300   FORMAT (1H ,10X,20HOUTLET WATER TEMP    ,4X,F9.2,1X,5HDEG.F)          CON38300
310   FORMAT (1H ,10X,9HHEAD LOSS,15X,F9.2,1X,6HFT H2O/11X,13HPUMPING POCON38310
     1WER,11X,F9.2,1X,2HHP/)                                               CON38320
320   FORMAT (1H ,10X,13HWATER FLOW    ,12X,1PE11.4,1X,5HLB/HR)             CON38330
330   FORMAT (1H ,10X,17HWATER VELOCITY    ,8X,1PE11.4,1X,6HFT/SEC/)        CON38340
340   FORMAT (1H ,10X,12HAVG. LMTD    ,14X,F7.2,1X,5HDEG.F)                 CON38350
350   FORMAT (1H ,10X,9HAVG. U    ,17X,F7.2,1X,18HBTU/HR-SQ.FT-DEG.F/)      CON38360
360   FORMAT (1H ,10X,46HTHE PERCENTAGE OF THE OUTERMOST ROW FILLED IS ,CON38370
     1F7.4//)                                                              CON38380
370   FORMAT (1H ,10X,18HTHE AREA RATIO IS ,F7.4//)                         CON38390
      END                                                                   CON38400
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```
C
C*****************************************************************
C*****************************************************************
C
      SUBROUTINE OUT2C
C-------------------
C
C                 SUMMARY OUTPUT FOR COOLER SECTION
C
C-------------------
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDC,VELBI,XW1,XW2,VOL1,VOL2,TNOTO
     2T,BNDRAC,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,S
     1TSAT1,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MD
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)
     3,WSI,PFILL
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMDOT(10
     10)
      COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNO,VEL2,FR
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,ACC,SUMQC,SDIC,SDOC,UBARW,SMWBC,
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AOT,BUNWT,AVTBI,AVTB2,WTSTC,VOLC
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEF
     1F(100,15),PMIX(100,15),PSAT(100,15),QOA(100,15),RC(100,15),ROUT(10
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)
     3,VNRE(100,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WS(100,15
     4),WSP(15)
      COMMON /COOL1/ VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100
     1),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),
     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QOAC(100),C
     3UMDPC(100)
      COMMON /COOL/ IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,T
     1B2C,ENHIC,ENHOC,ENHFC,SHWINC,WBC
      UBARWC=0.
      DO 10 J=1,IVNOC
      UBARWC=UBARWC+UNC(J)*HNOC
10    CONTINUE
      DELPVC=PMIXC(1)-PMIXC(IVNOC+1)
      UBARWC=UBARWC/TNOC
      AOTC=AOC*TNOC
      ADTCLR=SUMQC/(UBARWC*AOTC)
      TDROPC=STSATC(1)-STSATC(IVNOC+1)
      AVTBIC=SMTBIC/SMWBC
      AVTB2C=SMTB2C/SMWBC
      WDCLR=SDOC*SDDC*HNOC
      COOLWT=TUBESW*TNOC*ALST*PI*(SDOC*SDOC-SDIC*SDIC)/4.
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      VWBARC=VWBAR                                                          CON38890
C                                                                           CON38900
      IF (AVTBIC.EQ.AVTB2C) DTCOL2=0.                                       CON38910
      IF (AVTBIC.EQ.AVTB2C) UPCOOL=UBARWC                                   CON38920
      IF (AVTBIC.EQ.AVTB2C) GO TO 20                                        CON38930
C                                                                           CON38940
      DTCOL2=(AVTB2C-AVTBIC)/ALOG((STSATX-AVTBIC)/(STSATX-AVTB2C))          CON38950
      UPCOOL=SUMQC/(AOTC*DTCOL2)                                            CON38960
C                                                                           CON38970
C     VALUES FOR OVERALL OUTPUT                                             CON38980
C                                                                           CON38990
20    AOTOT=AOTC+AOT                                                        CON39000
      TNOT=TNC+TNOC                                                         CON39010
      UBAROA=(UBARW*TNO+UBARWC*TNOC)/TNOT                                   CON39020
      AOTOA=(SUMQC+SUMQ)/(UBAROA*AOTOT)                                     CON39030
      DELPOA=PMIX1-PMIXC(IVNOC+1)                                           CON39040
      TDRPOA=STSAT1-STSATC(IVNOC+1)                                         CON39050
      SUMQOA=SUMQC+SUMQ                                                     CON39060
      WTOA=BUNWT+COOLWT                                                     CON39070
      AVTBIA=(AVTBI*TNO+AVTBIC*TNOC)/TNOT                                   CON39080
      AVTB2A=(AVTB2*TNO+AVTB2C*TNOC)/TNOT                                   CON39090
      SMWBOA=SMWBC+SMWB                                                     CON39100
      HDLSOA=DELWP*144./62.366                                              CON39110
      DTOA=(AVTB2A-AVTBIA)/ALOG((STSAT1-AVTBIA)/(STSAT1-AVTB2A))            CON39120
      UPOA=SUMQOA/(AOTOT*DTOA)                                              CON39130
      WRITE (6,40)                                                          CON39140
      WRITE (6,50) UBARWC,ADTCLR,DELPVC,TDROPC,VELC(1),VELC(IVNOC)          CON39150
      WRITE (6,60) SUMQC                                                    CON39160
      WRITE (6,70) WSC(1)                                                   CON39170
      WRITE (6,110) AOTC                                                    CON39180
C                                                                           CON39190
      IF (EXITFC.LT.-900.) WRITE (6,100)                                    CON39200
      IF (EXITFC.LT.-900.) GO TO 30                                         CON39210
C                                                                           CON39220
      WRITE (6,80) EXITFC                                                   CON39230
C                                                                           CON39240
30    IF (WTSTC.LT.0) WRITE (6,90) WTSTC                                    CON39250
C                                                                           CON39260
      WRITE (6,120) TNOC,IVNOC                                              CON39270
      WRITE (6,130)                                                         CON39280
      WRITE (6,140) HTCLR,WDCLR                                             CON39290
      WRITE (6,150) VCLC,COOLWT                                             CON39300
      WRITE (6,160) AVTB                                                    CON39310
      WRITE (6,170) AVTB2C                                                  CON39320
      WRITE (6,180) SMWBC                                                   CON39330
      WRITE (6,190) VWBARC                                                  CON39340
      WRITE (6,210) DTCOL2                                                  CON39350
      WRITE (6,220) UPCOOL                                                  CON39360
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      WRITE (6,230) SDDC                                                    CON3$370
      WRITE (6,250)                                                         CON3$380
      WRITE (6,260) UBAROA,ADTOA,DELPOA,TDRPOA                              CON3$390
      WRITE (6,60) SUMQOA                                                   CON3$400
      WRITE (6,110) AOTOT                                                   CON3$410
      WRITE (6,80) EXITOA                                                   CON3$420
      WRITE (6,270) TNOT                                                    CON3$430
      WRITE (6,280) VOL1,WTOA                                               CON3$440
      WRITE (6,160) AVTB1A                                                  CON3$450
      WRITE (6,170) AVTB2A                                                  CON3$460
      WRITE (6,180) SMWBOA                                                  CON3$470
      WRITE (6,200) HQLSOA,PHP                                              CON3$480
      WRITE (6,210) DTOA                                                    CON3$490
      WRITE (6,220) UPOA                                                    CON3$500
      IF (PRCCLR.GT.0) WRITE (6,240) ARATIO                                 CON3$510
      RETURN                                                                CON3$520
   40 FORMAT (1HO,31X,29H********   COOLER    ********//)                   CON3$530
   50 FORMAT (1H ,10X,56HOVERALL U  LOG-MEAN  PRESSURE    TEMP.     STEAMCON3$540
     1 VELOCITY/10X,54HB/HR-DEG.F  DELTA T    DROP        DROP          FCON3$550
     2T/SEC/11X,57H-SQ.FT.     DEG.F        PSIA        DEG.F     INLET    OUCON3$560
     3TLET//12X,F6.2,3X,F6.2,4X,1PE9.2,1P3E10.2/)                         CON3$570
   60 FORMAT (1H ,10X,12HHEAT DUTY    ,8X,1PE11.4,2X,6HBTU/HR)             CON3$580
   70 FORMAT (1H ,10X,18HSTEAM TO COOLER    ,2X,1PE11.4,2X,5HLB/HR)      CON3$590
   80 FORMAT (1H ,10X,13HEXIT FRAC.    ,7X,1PE11.4/)                       CON3$600
   90 FORMAT (1H ,10X,39HIN COOLER, THE FRACTION OF DRY ROWS WAS,F10.6/)CON3$610
  100 FORMAT (1H ,10X,46HTHE COOLER IS ENTIRELY DRY AND THUS NO EXIT FR/CON3$620
     1)                                                                    CON3$630
  110 FORMAT (1H ,10X,19HHT. TRF. SURF. AREA,1X,1PE11.4,2X,6HSQ.FT.)      CON3$640
  120 FORMAT (1H ,14X,11HDIMENSIONS,,7X,2HFT,7X,F10.2,1X,6HTUBES,,I5,1X,CON3$650
     14HROWS)                                                              CON3$660
  130 FORMAT (1H ,12X,6HHEIGHT,5X,5HWIDTH)                                 CON3$670
  140 FORMAT (1H ,12X,F5.2,5X,F5.2/)                                       CON3$680
  150 FORMAT (1H ,10X,19HTOTAL COOLER VOLUME,1X,1PE11.4,2X,6HCU.FT./11X,CON3$690
     115HCOOLER WEIGHT   ,1X,1PE11.4,2X,2HLB/)                            CON3$700
  160 FORMAT (1H ,10X,19HINLET WATER TEMP    ,5X,F9.2,1X,5HDEG.F)        CON3$710
  170 FORMAT (1H ,10X,20HOUTLET WATER TEMP   ,4X,F9.2,1X,5HDEG.F)        CON3$720
  180 FORMAT (1H ,10X,13HWATER FLOW    ,9X,1PE11.4,1X,5HLB/HR/)           CON3$730
  190 FORMAT (1H ,10X,17HWATER VELOCITY    ,5X,1PE11.4,1X,6HFT/SEC/)     CON3$740
  200 FORMAT (1H ,10X,9HHEAD LOSS,15X,F9.2,1X,6HFT H2O/11X,13HPUMPING POCON3$750
     1WER,11X,F9.2,1X,2HHP/)                                              CON3$760
  210 FORMAT (1H ,10X,12HAVG. LMTD    ,14X,F7.2,1X,5HDEG.F)               CON3$770
  220 FORMAT (1H ,10X,9HAVG. U    ,17X,F7.2,1X,18HBTU/HR-SQ.FT-DEG.F)     CON3$780
  230 FORMAT (1H ,10X,35HTHE COOLER CIRCUMFERENTIAL PITCH IS,2X,F6.2//)  CON3$790
  240 FORMAT (1H ,10X,26HTHE OVERALL AREA RATIO IS ,F7.4//)              CON3$800
  250 FORMAT (1HO,31X,29H********   OVERALL    ********//)               CON3$810
  260 FORMAT (1H ,10X,38HOVERALL U  LOG-MEAN  PRESSURE    TEMP./10X,36HBCON3$820
     1/HR-DEG.F  DELTA T    DROP        DROP/11X,37H-SQ.FT.     DEG.F      PCON3$830
     2SIA      DEG.F//12X,F6.2,3X,F6.2,4X,1PE9.2,1PE10.2/)               CON3$840
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```
  270   FORMAT (1H /12X,F10.2,2X,5HTUBES/)                                    CON39850
  280   FORMAT (1H ,10X,12HTOTAL VOLUME,7X,1PE11.4,2X,6HCU.FT./11X,14HTOTA    CON39860
     1L WEIGHT  ,5X,1PE11.4,2X,2HLB/)                                         CON39870
        END                                                                   CON39880
C                                                                             CON39890
C*****************************************************************          CON39900
C*****************************************************************          CON39910
C                                                                             CON39920
      SUBROUTINE OUT3                                                         CON39930
C-------------                                                                CON39940
C OUT3 1                                                                      CON39950
C                    DETAILED OUTPUT                                          CON39960
C ZZZ OUT3-1                                                                  CON39970
C-------------                                                                CON39980
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,      CON39990
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNOTO     CON40000
     2T,BNDRAC,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR                            CON40010
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON40020
     1TSAT1,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON40030
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON40040
     3,WSI,PFILL                                                              CON40050
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMDOT(10CON40060
     10)                                                                      CON40070
      COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)                                CON40080
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNQ,VEL2,FR                    CON40090
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,ACC,SUMQC,SDIC,SDOC,UBARW,SMWBC,CON40100
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AOT,BUNWT,AVTBI,AVTB2,WTSTC,VOLC CON40110
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST                               CON40120
      COMMON /COOL1/ VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100CON40130
     1),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),CON40140
     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QOAC(100),CCON40150
     3UMDPC(ICO)                                                              CON40160
      COMMON /COOL/ IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,TCON40170
     1B2C,ENHIC,ENHOC,ENHFC,SHWINC,WBC                                        CON40180
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEFCON40190
     1F(100,15),PMIX(100,15),PSAT(100,15),QOA(100,15),RC(100,15),ROUT(10CON40200
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)CON40210
     3,VNRE(100,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WS(100,15CON40220
     4),WSP(15)                                                               CON40230
      ROWS=FLOAT(NOROWS)                                                      CON40240
      IF (MDIAM.EQ.1) ODII=ODOI                                               CON40250
      IF (MPITCH.EQ.1) SDDI=SDDO                                              CON40260
      DELSDD=(SDDO-SDDI)/(ROWS-1.)                                            CON40270
      WRITE (6,140)                                                           CON40280
      DO 10 I=1,NOROWS                                                        CON40290
      A=CMDOT(I)*3600.                                                        CON40300
      OD=ODOI-DELOD*FLOAT(I-1)                                                CON40310
      SDD=SDDO-DELSDD*FLOAT(I-1)                                              CON40320
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10      WRITE (6,160) I,VW(I),A,OD,SDD,TBNPR(I)                                  CON40330
        DO 30 J=1,ISEC                                                           CON40340
        WRITE (6,120) J                                                          CON40350
        DO 20 I=1,NOROWS                                                         CON40360
        OD=ODOI-DELOD*FLOAT(I-1)                                                 CON40370
        AO=3.14159*OD*ALST                                                       CON40380
        Q=UN(I,J)*ALMTD(I,J)*AO                                                  CON40390
20      WRITE (6,160) I,Q,CUMDP(I,J),ALMTD(I,J),RC(I,J),VNRE(I,J)                CON40400
30      CONTINUE                                                                 CON40410
        DO 50 J=1,ISEC                                                           CON40420
        WRITE (6,130) J                                                          CON40430
        DO 40 I=1,NOROWS                                                         CON40440
40      WRITE (6,160) I,UN(I,J),ROUT(I,J),HEFF(I,J),SHN(I,J),SHI(I,J)            CON40450
50      CONTINUE                                                                 CON40460
        DO 70 J=1,ISEC                                                           CON40470
        WRITE (6,150) J                                                          CON40480
        DO 60 I=1,NOROWS                                                         CON40490
60      WRITE (6,160) I,WS(I,J),WCND(I,J),STSAT(I,J),PSAT(I,J),PMIX(I,J)         CON40500
70      CONTINUE                                                                 CON40510
        IF (PRCCLR.LE.0.) GO TO 110                                              CON40520
        WRITE (6,170)                                                            CON40530
        DO 80 I=1,IVNOC                                                          CON40540
        QC=UNC(I)*ALMTDC(I)*AOC                                                  CON40550
        WRITE (6,200) I,QC,CUMDPC(I),ALMTDC(I),RCC(I),VNREC(I)                   CON40560
80      CONTINUE                                                                 CON40570
        WRITE (6,180)                                                            CON40580
        DO 90 I=1,IVNOC                                                          CON40590
        WRITE (6,200) I,UNC(I),ROUTC(I),HEFFC(I),SHNFC(I),SHIC(I)                CON40600
90      CONTINUE                                                                 CON40610
        WRITE (6,190)                                                            CON40620
        DO 100 I=1,IVNOC                                                         CON40630
        WRITE (6,200) I,WSC(I),WCNDC(I),STSATC(I),PSATC(I),PMIXC(I)              CON40640
100     CONTINUE                                                                 CON40650
110     RETURN                                                                   CON40660
120     FORMAT (1H1////15X,15X,28HROW BY ROW OUTPUT FOR SECTOR,I3//15X,3HCON40670
       1ROW,4X,4HHEAT,5X,8HPRESSURE,3X,8HLOG MEAN,3X,8HRATIO OF,2X,10HSTEACON40680
       2M SIDE/15X,3HNO.,2X,8HTRANSFER,5X,4HDROP,5X,9HTEMP DIFF,2X,7HN/C GCON40690
       3AS,3X,12HREYNOLDS NO./15X,5X,8HPER TUBE,3X,7HPER ROW,14X,10HTO STMCON40700
       4 FLW/15X,6X,6HBTU/HR,6X,3HPSI,8X,5HDEG F/)                               CON40710
130     FORMAT (1H1////15X,5X,47HROW BY ROW HEAT TRANSFER COEFICIENTS FORCON40720
       1 SECTOR,I3/15X,23X,14HBTU/HR-FT**2-F//15X,3HROW,2X,8HOVER-ALL,3X,8CON40730
       2HEXTERNAL,3X,8HEXTERNAL,3X,8HEXTERNAL,3X,8HINTERNAL/15X,3HNO.,4X,4CON40740
       3HTUBE,7X,4HTUBE,5X,8HGAS FILM,3X,8HLIQ FILM,3X,8HLIQ FILM/)              CON40750
140     FORMAT (1H1////15X,9X,41HROW BY ROW VALUES OF CONDENSER PARAMETERCON40760
       1S//15X,3HROW,3X,7HCOOLANT,2X,12HCOOLANT MASS,3X,4HTUBE,7X,4HTUBE,4CON40770
       2X,9HNUMBER OF/15X,3HNO.,3X,21HVELOCITY  FLOW/TUBE  ,4X,2HOD,8X,5HPCON40780
       3ITCH,3X,9HTUBES PER/15X,17X,6HLBM/HR,6X,6HINCHES,14X,11HROW PER SECON40790
       4C/)                                                                      CON40800
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150   FORMAT (1H1/////15X,4X,49HROW BY ROW STEAM AND CONDENSATE VALUES FCON40810
     1OR SECTOR,I3//15X,3HROW,3X,8HSTM FLOW,2X,10HCONDENSATE,1X,10HSATURCON40820
     2ATION,1X,10HSATURATION,2X,7HMIXTURE/15X,3HNO.,3X,8HENTERING,2X,9HGCON40830
     3ENERATED,4X,4HTEMP,5X,8HPRESSURE,3X,8HPRESSURE/15X,7X,6HLBM/HR,5X,CON40840
     46HLBM/HR,6X,5HDEG F,7X,3HPSI,8X,3HPSI/)                          CON40850
160   FORMAT (1H ,14X,I3,5(2X,1PE9.3))                                  CON40860
170   FORMAT (1H1/////15X,15X,28HROW BY ROW OUTPUT FOR COOLER//15X,3HROWCON40870
     1,4X,4HHEAT,5X,8HPRESSURE,3X,8HLOG MEAN,3X,8HRATIO OF,2X,10HSTEAM SCON40880
     2IDE/15X,3HNO.,2X,8HTRANSFER,5X,4HDROP,5X,9HTEMP DIFF,2X,7HN/C GAS,CON40890
     33X,12HREYNOLDS NO./15X,5X,8HPER TUBE,3X,7HPER ROW,14X,10HTO STM FLCON40900
     4W/15X,6X,6HBTU/HR,6X,3HPSI,8X,5HDEG F/)                          CON40910
180   FORMAT (1H1/////15X,5X,47HROW BY ROW HEAT TRANSFER COEFICIENTS FORCON40920
     1 COOLER/15X,23X,14HBTU/HR-FT**2-F//15X,3HROW,2X,8HOVER-ALL,3X,8HEXCON40930
     2TERNAL,3X,8HEXTERNAL,3X,8HEXTERNAL,3X,8HINTERNAL/15X,3HNO.,4X,4HTUCON40940
     3BE,7X,4HTUBE,5X,8HGAS FILM,3X,8HLIQ FILM,3X,8HLIQ FILM/)         CON40950
190   FORMAT (1H1/////15X,4X,49HROW BY ROW STEAM AND CONDENSATE VALUES FCON40960
     1OR COOLER//15X,3HROW,3X,8HSTM FLOW,2X,10HCONDENSATE,1X,10HSATURATICON40970
     2ON,1X,10HSATURATION,2X,7HMIXTURE/15X,3HNO.,3X,8HENTERING,2X,9HGENECON40980
     3RATED,4X,4HTEMP,5X,8HPRESSURE,3X,8HPRESSURE/15X,7X,6HLBM/HR,5X,6HLCON40990
     48M/HR,6X,5HDEG F,7X,3HPSI,8X,3HPSI/)                             CON41000
200   FORMAT (1H ,14X,I3,5(2X,1PE9.3))                                  CON41010
      END                                                               CON41020
C                                                                       CON41030
C*************************************************************************CON41040
C                          SUPPORTING SUBROUTINES                       CON41050
C*************************************************************************CON41060
C                                                                       CON41070
      SUBROUTINE DFSVTY (TK,PATM,AM1,AM2,R1,R2,E10K,E20K,V1,V2,DG,DGG)  CON41080
C  DG = GAS DIFFUSIVITY, SQ.CM./SEC - CHEM.ENGRS.HANDBOOK, 4TH ED.,     CON41090
C  R.H.PERRY, 14-20, 1963, MC GRAW-HILL  (WILKE-LEE MOD.)               CON41100
C  CID = VALUES OF COLLISION INTEGRAL. FUNCTION FITTED BY R.W.BROWELL   CON41110
C        FROM TABLE 14-45 OF ABOVE REF. 4/11/68                        CON41120
C  TK  = ABS. TEMP., DEG. KELVIN                                        CON41130
C  PATM= ABS. PRESS., ATMOSPHERES                                       CON41140
C  R12 = COLLISION DIA., ANGSTROMS                                      CON41150
C  R1  = COMPONENT 1 COLLISION DIA., ANGSTROMS                          CON41160
C  R2  = COMPONENT 2 COLLISION DIA., ANGSTROMS                          CON41170
C E12OK= COMBINED FORCE CONSTANT FOR COMPONENTS 1 & 2., DEG. KELVIN     CON41180
C  DGG = GAS DIFFUSIVITY - GILLILAND'S CRUDE APPROX. METHOD,PP.14-21 REFCON41190
      IF (E1OK.EQ.0.0.AND.V1.EQ.0.0) GO TO 30                           CON41200
      IF (E1OK.EQ.0.0) GO TO 20                                         CON41210
      IF (R1.GT.0.0) GO TO 10                                           CON41220
      R1=1.18*V1**.333                                                  CON41230
      R2=1.18*V2**.333                                                  CON41240
10    CONTINUE                                                          CON41250
      R12=(R1+R2)/2.0                                                   CON41260
      E12OK=(E1OK*E2OK)**0.5                                            CON41270
      TKOE=TK/E12OK                                                     CON41280
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      CID=0.1685/TKOE**1.2063+0.5328/TKOE**0.1579                          CON41290
      RTSM=(1./AM1+1./AM2)**0.5                                            CON41300
      B=(10.7-2.46*RTSM)*1.E-4                                             CON41310
      DG=B*TK**1.5*RTSM/PATM/R12**2/CID                                    CON41320
      IF (V1.EQ.0.0) GO TO 40                                              CON41330
   20 CONTINUE                                                             CON41340
      DGG=0.0043*TK**1.5*RTSM/PATM/(V1**.333+V2**.333)**2                  CON41350
      GO TO 40                                                             CON41360
   30 CONTINUE                                                             CON41370
      WRITE (6,50)                                                         CON41380
   40 CONTINUE                                                             CON41390
      RETURN                                                               CON41400
   50 FORMAT (103H0  ** NEITHER FORCE CONSTANTS NOR MOLECULAR VOLUMES EXCON41410
     1IST AS ARGUMENTS. CALCULATIONS CANNOT PROCEED. **)                   CON41420
      END                                                                  CON41430
C                                                                          CON41440
C                                                                          CON41450
      FUNCTION XTR (X,Y,N,T,SW,X1N,YN,M)                                   CON41460
C******                                                                    CON41470
C         FUNCTION XTR ASSUMES A LOG-LOG MODEL, IE  LOG Y = A + B1 * LOG   CON41480
C         AND PERFORMS A LINEAR LEAST SQUARE REGRESSION ON THE             CON41490
C         TRANSFORMED POINTS, ALL POINTS ARE USED FOR EACH REGRESSION      CON41500
C         EXCEPT FOR THE FIRST , WHICH IS NOT USED AT ALL                  CON41510
C********                                                                  CON41520
      DIMENSION X1N(11),YN(11)                                             CON41530
      IF (Y.LE.0.) Y=.00001                                                CON41540
      IF (N.EQ.0) GO TO 30                                                 CON41550
      X1N(N)=ALOG(X)                                                       CON41560
      YN(N)=ALOG(Y)                                                        CON41570
      IF (N.LT.2) GO TO 40                                                 CON41580
      SX1N=0.0                                                             CON41590
      SYN=0.0                                                              CON41600
      IF (M.LT.N-3) M=N-3                                                  CON41610
      DO 10 I=M,N                                                          CON41620
      SX1N=SX1N+X1N(I)                                                     CON41630
      SYN=SYN+YN(I)                                                        CON41640
   10 CONTINUE                                                             CON41650
      X1BAR=SX1N/(N-M+1)                                                   CON41660
      YBAR=SYN/(N-M+1)                                                     CON41670
      SX12=0.0                                                             CON41680
      SX1Y=0.0                                                             CON41690
      DO 20 I=M,N                                                          CON41700
      SX12=SX12+(X1N(I)-X1BAR)**2                                          CON41710
      SX1Y=SX1Y+(X1N(I)-X1BAR)*(YN(I)-YBAR)                                CON41720
   20 CONTINUE                                                             CON41730
      B1=SX1Y/SX12                                                         CON41740
      A=YBAR-B1*X1BAR                                                      CON41750
      TN=ALOG(T)                                                           CON41760
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      XTR=EXP((TN-A)/B1)                                                CON41770
      GO TO 50                                                          CON41780
30    M=1                                                               CON41790
40    XTR=X*(1.+(Y-T)*5.*SW)                                            CON41800
C*****                                                                  CON41810
C        CHANGE OF VARIABLE IS LIMITED TO 10 PERCENT                    CON41820
C*****                                                                  CON41830
50    IF (ABS(XTR-X)/X.LT.0.1) GO TO 60                                 CON41840
      XTR=X*(1.+0.1*ABS(Y-T)/(Y-T)*SW)                                  CON41850
60    RETURN                                                            CON41860
      END                                                               CON41870
C                                                                       CON41880
C                                                                       CON41890
      FUNCTION AMUFN (T,JGAS)                                           CON41900
      IMIX=0                                                            CON41910
      GO TO (30,20,10), JGAS                                            CON41920
10    IMIX=1                                                            CON41930
20    CONTINUE                                                          CON41940
C  INERT GAS IS CO2                                                     CON41950
C**  VISCOSITY FOR CARBON DIOXIDE  LB/FT-SEC                           CON41960
      GAS2=1.0E-5*(-0.046+(2.282E-3+(-6.131E-7+9.699E-11*T)*T)*T)       CON41970
      AMUFN=GAS2                                                        CON41980
      IF (IMIX.EQ.0) RETURN                                             CON41990
30    CONTINUE                                                          CON42000
C  INERT GAS IS AIR                                                     CON42010
      GAS1=1.0E-5*(0.1490+(0.238E-2)*T-(.7209E-6)*T**2+(.1184E-9)*T**3) CON42020
      AMUFN=GAS1                                                        CON42030
      IF (IMIX.EQ.0) RETURN                                             CON42040
C  INERT GAS IS MIXTURE OF AIR & CO2                                    CON42050
      GAS3=(GAS1+GAS2)/2.0                                              CON42060
      AMUFN=GAS3                                                        CON42070
      RETURN                                                            CON42080
      END                                                               CON42090
C                                                                       CON42100
C                                                                       CON42110
      FUNCTION BMUFN (C,T)                                              CON42120
C     VISCOSITY OF SALINE SOLUTION.  RANGE OF DATA WAS 0 - 24 PERCENT   CON42130
C     CONCENTRATION AND 40 - 210 DEGREES FARENHEIT.                     CON42140
      R=T+459.69                                                        CON42150
      BMUFN=DEXP(-0.11591155D+2*C+0.12602329D-1*C*R+0.38637378D+4*C/R+0. CON42160
     1460653 2D-2*R+0.47595941D+4/R-0.1059252566D+2)                    CON42170
      RETURN                                                            CON42180
      END                                                               CON42190
C                                                                       CON42200
C                                                                       CON42210
      FUNCTION CPAFN (T,JGAS)                                           CON42220
      IMIX=0                                                            CON42230
      GO TO (30,20,10), JGAS                                            CON42240
```

```
10      IMIX=1                                                                  CON42250
20      CONTINUE                                                                CON42260
C  INERT GAS IS CO2                                                             CON42270
C** HEAT CAPACITY FOR MW = 40.1    BTU/LB-MOL - DEG R                           CON42280
        GAS2=0.209*40.1                                                         CON42290
        CPAFN=GAS2                                                              CON42300
        IF (IMIX.EQ.0) RETURN                                                   CON42310
30      CONTINUE                                                                CON42320
C  INERT GAS IS AIR                                                             CON42330
C AIR CP, BTU / LB MOLE-DEGREE RANKIN                                           CON42340
        GAS1=7.139-0.9884E-3*T+0.1393E-5*T**2-0.3367E-9*T**3                    CON42350
        CPAFN=GAS1                                                              CON42360
        IF (IMIX.EQ.0) RETURN                                                   CON42370
C  INERT GAS IS MIXTURE OF AIR & CO2                                            CON42380
        GAS3=(GAS1+GAS2)/2.0                                                    CON42390
        CPAFN=GAS3                                                              CON42400
        RETURN                                                                  CON42410
        END                                                                     CON42420
C                                                                               CON42430
C                                                                               CON42440
        FUNCTION CPFN (C,T)                                                     CON42450
10      IF (C-0.005) 20,20,30                                                   CON42460
C*****EQUATION SPECIFIC HEAT FOR PURE WATER                                     CON42470
20      CP=1.0121559+(-0.24618473E-3+0.10282155E-5*T)*T                         CON42480
        GO TO 40                                                                CON42490
C*****EQUATION SPECIFIC HEAT FOR BRINE                                          CON42500
30      CP=.96946859+(2.*(0.00010404965)*T)-(.91199294*C)+(2.*(-.000648296      CON42510
     1591)*C*T)+(-1.555779*(C**2))+(2.*(.007672146)*(C**2)*T)+(6.7981008        CON42520
     2*(C**3))+(2.*(-.012610354)*(C**3)*T)                                      CON42530
40      CPFN=CP                                                                 CON42540
        RETURN                                                                  CON42550
        END                                                                     CON42560
C                                                                               CON42570
C                                                                               CON42580
        FUNCTION CPSFN (T)                                                      CON42590
C***                                                                            CON42600
C     CPSFN CALCULATES THE HEAT CAP OF STEAM IN BTU/LB-MOL-R GIVEN T IN         CON42610
C     DEG R.  EQUATIONS FROM H. NORITAKE, BASED ON TABULATED VALUES IN          CON42620
C     NASA TR-R-132                                                             CON42630
C***                                                                            CON42640
        CPSFN=(7.838-(.2531E-3-(.2892E-6-.7693E-10*T)*T)*T)                     CON42650
        RETURN                                                                  CON42660
        END                                                                     CON42670
C                                                                               CON42680
C                                                                               CON42690
        FUNCTION HFGFN (T)                                                      CON42700
        HFGFN=1093.88-0.5703*T+.00012819*T**2-.0000008824*T**3                  CON42710
        RETURN                                                                  CON42720
```

```
      END                                                                    CON42730
C                                                                            CON42740
C     SUBROUTINE PRSDRP (TSAT,VMIX,WS,WNC,AXC,SDO,SF,DELPTP,ENHF)            CON42750
C                                                                            CON42760
CCC                                                                          CON42770
C   PRSDRP  REBUILT ON 9-16-69 TO USE EQUATION FOR SF                        CON42780
CCC                                                                          CON42790
      SG=32.174                                                              CON42800
      GSTAR=(WS+WNC)/(AXC*3600.)                                             CON42810
      ANRE=(SDO*GSTAR)/SMUFN(TSAT)                                           CON42820
      SF=(0.102+52.2/ANRE)*ENHF                                              CON42830
      DELPTP=SF*GSTAR**2*VMIX/(72.0*SG)                                      CON42840
      RETURN                                                                 CON42850
      END                                                                    CON42860
C                                                                            CON42870
C     FUNCTION PSATFN (T)                                                    CON42880
      PSATFN=2.718**(14.150119-(6452.5621/T)-(837533.21/T**2))               CON42890
      RETURN                                                                 CON42900
      END                                                                    CON42910
C                                                                            CON42920
C     FUNCTION ROEFN (C,T)                                                   CON42930
C     DENSITY OF SALINE SOLUTION.  RANGE OF DATA WAS 0 - 26 PERCENT          CON42940
C     CONCENTRATION AND 40 - 300 DEGREES FARENHEIT.                          CON42950
      ROEFN=0.62707172E2+0.49364088E2*C-(0.43955304E-2+0.32554667E-1*C+(     CON42960
     1 0.46076521E-4-0.63240299E-4*C)*T)*T                                   CON42970
      RETURN                                                                 CON42980
      END                                                                    CON42990
C                                                                            CON43000
C     FUNCTION SKBFN (C,T)                                                   CON43010
C           THERMAL CONDUCTIVITY OF SALINE SOLUTION.  RANGE OF DATA          CON43020
C           0 - 24 PERCENT CONCENTRATION AND 40 - 300 DEGREES FARENHEIT      CON43030
      SKBFN=(.30157913+.697989E-3*T-.12506E-5*T**2-.2072E-10*T**3)*(-.16     CON43040
     1 87109*C+1.)                                                           CON43050
      RETURN                                                                 CON43060
      END                                                                    CON43070
C                                                                            CON43080
C     FUNCTION SMUFN (T)                                                     CON43090
      SMUFN=1.0E-5*(0.122+(1.001E-3)*T+(2.892E-7)*T**2-(7.693E-11)*T**3)     CON43100
      RETURN                                                                 CON43110
      END                                                                    CON43120
C                                                                            CON43130
C     FUNCTION TSATFN (P)                                                    CON43140
      AA=(ALOG(P)-14.150119)                                                 CON43150
                                                                             CON43160
                                                                             CON43170
                                                                             CON43180
                                                                             CON43190
                                                                             CON43200
```

```
      DET=6452.5621**2-(4.0*AA*837533.21)                                    CON43210
      IF (DET) 10,20,20                                                      CON43220
10    WRITE (6,60)                                                           CON43230
      CALL EXIT                                                              CON43240
20    X=(-6452.5621+SQRT(DET))/(2.0*AA)                                      CON43250
      Y=(-6452.5621-SQRT(DET))/(2.0*AA)                                      CON43260
      IF (X-Y) 30,40,40                                                      CON43270
30    TSATFN=Y                                                               CON43280
      GO TO 50                                                               CON43290
40    TSATFN=X                                                               CON43300
50    CONTINUE                                                               CON43310
      RETURN                                                                 CON43320
60    FORMAT (1H1,37HSUBROUTINE TSATFN FINDS COMPLEX ROOTS)                  CON43330
      END                                                                    CON43340
C                                                                            CON43350
C                                                                            CON43360
      FUNCTION VGFN (T,P)                                                    CON43370
      X=ALOG(T/P)                                                            CON43380
      VGFN=EXP(((.103758E-2*X-.0177861)*X+1.10267)*X-.72240)                 CON43390
      RETURN                                                                 CON43400
      END                                                                    CON43410
C                                                                            CON43420
C                                                                            CON43430
      SUBROUTINE SWITCH (A,N)                                                CON43440
      DIMENSION A(N)                                                         CON43450
      NN=N/2                                                                 CON43460
      K=N+1                                                                  CON43470
      DO 10 I=1,NN                                                           CON43480
      T=A(I)                                                                 CON43490
      A(I)=A(K-I)                                                            CON43500
      A(K-I)=T                                                               CON43510
10    CONTINUE                                                               CON43520
      RETURN                                                                 CON43530
      END                                                                    CON43540
```

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